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Support of Environmental Program Planning

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Final Report

SUPPORT OF ENVIRONMENTAL PROGRAM PLANNING

Sponsored by:

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
ARLINGTON, VIRGINIA 22209

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STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

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13. ABSTRACT

Principal environmental problem areas of importance to the Department of Defense were identified and possible approaches to advanced research projects directed toward solutions of these problems were suggested to provide partial source material in support of ARPA's research program planning. Topics regarding environmental impact analysis, resources management, air quality, water quality, materials handling and disposal, data management and special problems were included. For each topic, information was organized according to statement of the problem, state of the art, present activities and organization, implications for the DoD, and recommendations for further studies.

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Menlo Park, California 94025 · U.S.A.

Final Report *October 1972*

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Compiled by: JAMES L. MACKIN and RICHARD A. SCHMIDT

Prepared for and Funded by:

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PREFACE

This report identifies a number of environmental problem areas of present and possible future concern to the Department of Defense, and notes that in spite of recent progress, much remains to be done in dealing with environmental quality problems. The design of research programs to attack these problems will demand great care, as will the management of resulting data so as to realize their full potential. To this end, possible approaches to advanced research projects are suggested to provide partial source material in support of ARPA's research program planning. Topics regarding environmental impact analysis, resources management, air quality, water quality, materials handling and disposal, data management, and special problems are included. For each topic, information is organized according to statement of the problem, state of the art, present activities and organization, implications for the DoD, and recommendations for further studies.

A partial listing of recommended research problem areas, and a gross ordering of priorities for candidate projects, include the following:

(1) Determination of unit environmental impact data by class of activity and media to permit assessment of impacts and evaluation of standards, criteria, and programs intended to achieve environmental quality.

- Examples: environmental impact analysis, environmental aspects of resource development, development of environmental indices, and air pollution studies on an extended scale.

(2) Compilation and evaluation of environmental data to determine environmental effects and analyze intermedia interactions.

Examples: environmental effects framework and environmental monitoring, and total environmental interaction assessment.

(3) Alternative technology to control pollution at its source and conserve resources.

- Examples: atmospheric contamination, aerial surveillance spill prevention system, combat training electronic simulation, and hazardous waste disposal.

(4) Remedial technology to alleviate problems stemming from previous practices.

- Examples: oil spill cleanup techniques, noise, and pesticides.

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CHAPTER THREE ENVIRONMENTAL IMPACT ANALYSIS

CHAPTER FOUR RESOURCES MANAGEMENT

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I INTRODUCTION

In response to Executive Order 11507, which established the President's policy with respect to the protection and enhancement of the quality of the environment, the Department of Defense (DoD) is increasingly directing activity and resources to environmental quality management. These actions range from reorganizations and reassignments at higher echelons within DoD and the services to cleanup activities at individual bases and units throughout the country and overseas. To ensure coordination of the services in executing environmental quality policy, the Secretary of Defense has assigned broad responsibilities to the Assistant Secretary of Defense for Health and Environment* and in turn to the Deputy Assistant Secretary for Environmental Quality. The Office of the Deputy Assistant Secretary promotes coordination among the services concerning environmental actions and then coordinates with the Council on Environmental Quality, the Environmental Protection Agency, and other governmental agencies.

At the present time, attention is directed to pressing needs concerned with organizational problems; the development and implementation of environmental quality policy; environmental protection and enhancement programs, including international programs; evaluation of the environmental impact of DoD actions; and selected major problems related to oil and hazardous materials, noise pollution, deep water dumping, and disposition of herbicides and pesticides.† Although the majority of these activities are currently carried out in response to immediate needs, it is recognized that a

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* See Appendix B-AR-2.

† See Appendix B-AR-28.

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comprehensive long view is needed to avoid a continuing reaction to crisis situations that detract from the basic national security mission of the Department of Defense.

To promote the development of a long range environmental quality research program, the DoD, acting through the Defense Director of Research and Engineering, the Defense Advanced Research Projects Agency (ARPA), and the several services, has been reviewing ongoing DoD environmental activity,* including a number of armed services environmental impact statements, with a view to identifying areas that may be characterized by weaknesses in current theory and technology.

To assist in this work, Stanford Research Institute in April 1972 began a series of discussions with representatives of the Defense Advanced Research Projects Agency that resulted in this effort to provide technical support to ARPA's environmental program planning activities. The objectives of the effort were to identify principal environmental considerations of importance to the DoD and to develop a recommended research plan to be conducted by ARPA. In the time available for the study, the Institute could not, and did not, attempt to perform a comprehensive review of the entire environmental field of interest to ARPA and the DoD. Rather, within the general framework discussed below, the staff, in cooperation with the sponsor, selected areas of interest that emanated from reviews of existing DoD environmental impact statements and broader consideration of environmental quality problems that might result from DoD activities. The result of the effort is to provide partial source material to assist

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* An important, current activity related to ongoing and planned environmental research is being conducted by the Office of the Director of Defense Research and Engineering, Environmental and Life Sciences. Selected representatives from each of the services and other DoD components are preparing an area coordinating paper that, among other goals, will develop necessary R&D programs to meet needs and establish DoD resource requirements and priorities.

ARPA in developing its research program plans, together with recommendations for prospective research projects addressed to present or potential environmental quality problems.

In accomplishing this assignment, SRI assembled an interdisciplinary team of professional staff members knowledgeable in resources management; air quality; water quality; materials handling and disposal; data management systems; and specialized topics including noise problems, environmental impact assessment, and radiation. Working from selected problems of interest that were developed insofar as possible from an analysis of DoD activities, each member prepared a paper from the standpoint of his own experience and expertise. For each topic considered, information was organized as follows: statement of the problem, state of the art, present activities and organizations, implications for DoD, and recommendations for further studies. Cited references are listed either as footnotes or at the end of the specific section.

The time available for the study did not permit analysis of each topic in equal manner, and as a result, the depth and breadth of coverage varies among the several study areas that follow. In some cases, it was possible only to indicate the outline of problems and to sketch prospective approaches, while in other cases more complete and detailed treatment of problems were considered and more definite approaches to their solution were prepared. It is clear that far greater time than was available for this study is required to develop logical research programs to deal with several of the complex problems identified. Nevertheless, inclusion of even brief, outline descriptions of such problem areas in this report is believed justifiable in that it serves to place such matters on the agenda for future attention. In short, the fact that some topics are discussed at length and others only briefly does not necessarily indicate their relative importance or the amount of effort expended in their preparation.

The study team has endeavored to identify, in gross terms, recommendations for research priorities consistent with the tentative structures. In presenting these recommendations, the team makes no determination as to which organizations (public or private) should perform work. Instead, we have attempted to recognize research areas of importance to the DoD as an aid in its ongoing planning process, regardless of the ultimate sources of the data.

Stanford Research Institute welcomed the opportunity to undertake a task of such importance for the Defense Advanced Research Projects Agency. It is hoped that the information included in this report will facilitate ARPA's planning task and lead the way to progress in addressing environmental quality considerations of importance to the DoD.

SRI staff members who contributed directly to this report include:

George G. Barnes	Environmental Impact Assessment
David N. Berg	Environmental Data Management
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I SUMMARY AND RECOMMENDATIONS

A. Overview

One of the most important societal problems requiring increasing attention in coming years is the relationship of man to his environment. Environmental degradation is a natural process on earth. However, man's actions can alter the rates of natural processes, impose incompatible conditions on local areas, and undertake activities that may result in long-standing impact on environmental quality leading to impairment of amenities or permanent loss of needed future resources.

There is a rapidly growing concern about the condition of the physical environment, about pollution from many sources, and about the appropriate management and conservation of natural resources. This concern was highlighted by passage of significant new legislation at all levels of government in recent years. However, public concern and resolve to do something regarding the problem is only part of the ultimate solution. A great deal of technical work is required to define the scope and intensity of environmental impacts to arrive at realistic assessments of their effects and determine relative costs and benefits related to their treatment. These details are crucial to the success of any program to promote environmental quality and achieve effective resource management; yet each must be viewed in perspective so as to avoid dealing in symptoms that result in short term "solutions" to long term problems.

If the nation is to maintain its status of economic activity, the environmental crisis must be dealt with, and the means of carrying out public and private activities in manners compatible with environmental considerations must be established. A key problem is that the views of diverse groups toward environmental matters will differ. Each will have its own opinion on what constitutes a quality environment. These opinions typically include value judgments that reflect the interests of the groups, and this tends to frustrate attempts to achieve objectivity. To arrive at any analytical assessment of environmental influences, unbiased and objective data are required in sufficient depth and breadth to permit decision-makers to select practical, environmentally sound courses of action from an array of potential choices.

The present environmental situation is well illustrated by the diverse and widespread activities of the Department of Defense. These activities are such that great care in analysis of environmental impacts is required to avoid convenient and attractively simple approaches that may fail to achieve their intended purposes and may even lead to worse conditions. To guide such analyses, it might be useful to use a working definition of a quality environment as one in which the adverse effects of any given DoD activity on other essential or desirable activities are minimized to the point of nonsignificance.

The contribution of advanced research in addressing environmental problems positively can be of great importance to the DoD and the nation. Such work can clarify the present scale and intensity of environmental effects and lead to recognition of prospective approaches to ameliorate adverse effects. In this regard, it will be important to address the sources of pollutants and their causes so that research can be directed toward improved processes or procedures that yield fewer unwanted by-products or pollutants. A number of environmental problem areas are discussed in this report, and recommendations for further work are presented in support of the environmental program planning activity of the Defense Advanced Research Projects Agency (ARPA). Although the short time available for this study did not permit treatment of each problem area in comparable depth, tentative conclusions regarding possible further work were reached. Finally, research priorities are suggested in gross terms to aid in ARPA's preparation of a comprehensive environmental and resource management program plan.

B. Environmental Impact Analysis

Although a principal aim of scientific research is to solve problems, the choice and statement of a research problem is often more difficult than finding an appropriate solution and in many cases can even indicate the solution itself. In the area of environmental quality research, a very significant portion of the problems arises in response to conflicts and controversy. In response, many government agencies have attempted to focus on actual or potential conflict situations to structure their programs. However, this approach usually deals in short term situations, and the underlying causes of long term problems remain untreated. To correct this condition, a procedure to facilitate the perception and prediction of potential problems is needed, particularly for activities that are not governed by a set of specified regulations or standards. To address this basic problem, this study has initiated a systematic attempt to develop a logical framework for isolating problems that can be identified as a consequence of DoD activities and from them derive appropriate responses in the form of needed actions, including recommendations for required research.

The methodology is described by a series of sequential steps comprising the following key elements:

- Acquisition, synthesis, and analysis of collected information
- Breakdown of information into categories and subcategories of DoD activity

- Environmental impact analysis based on activities and associated impacts
- Examination of effects of impacts in terms of environmental cause-effect relationships
- Identification of problem areas associated with the state of current knowledge concerning environmental effects
- Identification of recommended research directed to problems of interest to ARPA.

The first steps consisted primarily of data gathering activities, and during the present study included the collection and review of 42 selected DoD Environmental Impact Statements. Although these statements constitute a potentially useful source of information for structuring DoD activities, they were found to be too restricted at the present time in number, scope, and content to be used in preparing a comprehensive activity analysis. Nevertheless, their future application to this purpose could be useful. Moreover, the environmental impact assessment process necessarily must reflect planned activities, and as a consequence a continuing and systematic review of the statements on a DoD-wide basis could provide improved environmental feedback information to the planning process, as required by the National Environmental Policy Act (P.L. 91-190).

The next steps in the analysis required evaluation of the assembled information in terms of types of actions or activities. At this point, which is critical for the logical development of outputs that recognize appropriate targets for research, cause and effect relationships need to be derived to translate activities into environmental impacts.

At the present time, no rigorous methods exist for quantitative evaluation of environmental effects from impacts, nor is it likely that quantitative methods can be developed to describe all the complicated phenomena that are entailed. What can be and is being done, however, is to establish orderly and systematic methods that can provide a high degree of assurance that the majority of impacts can be recognized, even if each environmental effect cannot be predicted with certainty. Although it was not possible to examine in detail all the various techniques that are currently available for translating activities into environmental impacts and effects, a moderate effort was expended to development of methods to illustrate how identification of atmospheric impacts might be done. The method uses a cause-effect matrix to reveal whether a methodology exists for quantitatively relating the cause to the effect. The method focuses on cause-effect relationships that theory or observation suggest are important, but whose exact relationships are poorly defined. The main goal is to identify needs for additional research, but a subsidiary output is the recognition of potential impacts that then may be subject to critical review. Using this approach, a number of research areas were identified that relate to DoD activities and whose impacts at present are not well understood. They include:

- Releases of pollutants to the middle or upper troposphere and to the stratosphere or above--concentrations and composition
- Releases of pollutants to the middle or upper troposphere--effects relating to cloud formation and precipitation
  - Nature of emissions, primarily jet engines
  - Relationships between freezing nuclei or cloud condensation nuclei and emissions
- High altitude releases of heat and water vapor (middle and upper troposphere, stratosphere)--relationship to cloudiness
- Alteration of surface radiative and thermal properties--relationship to precipitation and fog formation
- Worldwide climatic changes (global circulation, percipitation patterns, temperature distribution, cloudiness)--relationship to releases of pollutants and heat or water vapor associated with particular DoD operations.

The above approach has common elements with others that were briefly reviewed or cited during the study. The methodology suggests that a combination of elements most appropriate to DoD activities may prove useful if developed further. Viewed during the present study as a means of identifying research requirements, it was evident that the techniques would also have ready applications by the DoD to environmental impact assessment work concerning activities and operations relative to environmental quality and resource conservation.

C. Resources Management

Resources were defined as energy and mineral raw materials that occur in the earth. These resources are commonly described as nonrenewable, indicating that nature does not replenish them within either the lifetime of man or the span of human experience. The fact that such resources are finite means that development can lead, ultimately, to exhaustion. Inefficiencies in resource development and use to achieve relatively short term benefits are of particular concern in this regard, since they contribute to potential long term economic problems and result in environmental impacts whose significance is only partially understood. The problem facing the nation is that the use of resources needs to be reassessed in terms of a new set of economic and environmental values that depart from traditional institutional and economic patterns.

Practices related to nearly every commodity or material produced and used in modern commerce influence the quality of the environment in some way. Accordingly, all facets of major industries should be examined to determine the nature and extent of these influences at each industrial stage; studies should include current and future quantities, production and manufacturing methods and alternatives, uses, and disposal methods. To illustrate the type of analysis required, this study summarized the historical and projected supply-demand characteristics of a few nonfuel resource-based industries. Factors of production, import, export, supply, consumption, price, reserves, and reserve life index were detailed where the data could be applicable to assessment of environmental influences. In each case, key factors representing problems in environmental control were briefly described. Although the data presented for the industries studied are not necessarily rigorous or complete, they illustrate the type of industry information that should be analyzed in detail and indicate the magnitude of effort required to determine the major portion of possible future environmental effects for materials important to the DoD.

The task of defining environmental aspects of resource development, unfortunately, is quite difficult. Past developments were frequently implemented to emphasize efficient and economic resource recovery, with little consideration being given to attendant environmental effects associated with disposal of resulting wastes. The previous practices for waste disposal by essentially uncontrolled release into the environment did not require data on their magnitude or character, and precise information on wastes from production of common materials is often lacking or at best incomplete. This information is essential if resource development practices are to be systematically evaluated to achieve lessened environmental impact. However, many of the data relating units of waste to units of production remain to be compiled and applied to place in perspective in terms of environmental impacts the balances of materials used in the several processes by which resources are developed.

The state of the art in assessment of unit environmental impacts of resource development was described according to (1) materials handled (an indicator of solid wastes), (2) emissions (an indicator of air quality), and (3) discharges (an indicator of water quality). These data were used, to the extent possible in this initial study, in considerations of the environmental aspects of materials important to the DoD. Data in each category were compiled and discussed. Two examples of the application of these data in an overall environmental assessment of materials were described, one in which the apparent impact of two materials (copper versus aluminum) is compared and the other in which the impact of a material used in a common application (steel in a typical car) is analyzed. In each case, the analysis is preliminary and intended only to demonstrate the concept that quantitative analysis of environmental aspects of resource development is feasible. In the future, this approach should be applied to the several materials whose supply-demand relationships were discussed in another section of the report.

As a final consideration, the environmental aspects of energy development and use by the DoD were discussed.

D. Air Quality

Air pollution problems cut across the whole range of DoD operations, from housing installations to manufacturing, transportation, and weapons systems. Increasingly stringent emission controls will have an effect on virtually all operations. The pollutants produced by a community--a city or an army installation--are primarily the result of energy generation for heat and power. The pollutants from these operations are related to the characteristics of fuels used at these facilities. Alternative methods of space heating using central power plants need to be reevaluated in the light of the better controls applicable to power plants, as well as of the need to conserve fuels in short supply. Distribution of energy in the form of hot air, steam, hot water, or electricity should also be considered.

Ground transportation (cars and trucks) is the primary source of several important pollutants, such as carbon monoxide, hydrocarbons, oxides of nitrogen, and lead. Here again the DoD shares in the production of these pollutants in proportion to their use. Since first generation control technology is becoming available for all these emissions, the DoD is in a particularly favorable position to evaluate promising methods under controlled conditions, such as the effect of low lead and lead free gasoline and the importance of tune-ups and relatively minor engine modifications. An alternative approach is the development of different engines. Here a wide range of possibilities exists, from modifications of existing piston-type engines such as stratified charge engines to other internal combustion engines such as gasoline turbines and Wankel engines.

Because of the enormous variety of materials handled with respect to manufacturing activities, only a detailed examination of each product area can provide the necessary information to control environmental quality degradation. These include obtaining data on:

- Each process emitting pollutants
- Pollutants emitted from each process
- Existing air pollution control equipment and systems
- Proposed control systems.

Much of the above information, and potentially considerably more, could be acquired by coordination and cooperation, if not by active participation by the DoD in current and planned regional air quality studies in the civilian sector. In particular, attention is focused on the St. Louis region where the EPA and other agencies are planning an extensive Regional Air Pollution Study (RAPS) that will include a detailed analysis of the sources of pollution, meteorological and chemical processes, and air quality. The study is expected to take four to five years for completion of the data acquisition phase, consisting of special field studies using atmospheric tracers, aircraft, mobile laboratories, and remote sensing instrumentation, as well as appropriate continuous/conventional measurement programs. These studies will afford opportunities for local DoD activities within the region to contribute and participate and could result in direct and indirect gains if the mechanisms were established at the regional and national levels. DoD could thus contribute actively to solutions of a community problem of which its local operations are an integral part--establishment of viable air quality standards and complicance with those standards.

The contribution of airplanes to air pollution is not well known, and studies are now going on to determine the emissions for jet engines under a variety of conditions, including ground level operations, where idling, taxiing, and testing are conducive to high local emissions. Combustion products within the troposphere appear to be well-dispersed and are usually rapidly removed through meteorological interactions. Stratospheric flights present a new dimension of air pollution because of the absence of mixing effects, resulting in long residence times. The emission of oxides of nitrogen at high altitudes is of particular concern because of its possible effect on the ozone layer. Studies of possible effects of flights at these altitudes are of considerable importance to prospective new aircraft configuration.

There appears to be a somewhat more localized, but nevertheless real, impact on the environment from the testing and firing of large rockets. There are about 35 U.S. space launchings per year and many more test firings of ICBMs, ground-to-ground missiles, and small satellites. A good many of these use solid propellant motors, which can produce high local concentrations of hydrochloric acid near ground level.

Similarly, the effects of the many species generated in rocket exhaust on the upper atmosphere are insufficiently known and need to be delineated more clearly.

Until recently all knowledge of the upper atmosphere (about 100 km) has been obtained by ground-based indirect methods. For example, the ionized layers of the upper atmosphere have been probed by sending radio signals skyward and examining the reflections. Only since 1945 has the exploration of the upper atmosphere been possible. Sounding rockets enabled direct measurements of atmospheric conditions, which led to the detection of X-rays and auroral particles, the first photographs of the solar ultraviolet spectrum, and the gathering of data on pressure, temperature, density, and composition of the atmosphere. Since these altitudes are too low for stable satellite orbits, the sounding rockets have remained the most important research tool.

There is a need to discover the origin of the unexpected chemical species in the upper atmosphere and to analyze the possible consequences of their presence if not occurring naturally. More broadly, an inventory of the species or other changes that have been or are being introduced needs to be made, and a model should be contrived to describe the reactions induced. Then the final disposition of the reaction products and resulting effects on the population, climate, and social, economic, and military systems could be assessed.

The possible adverse effects of extensive aircraft traffic in the stratosphere has recently become the subject of much concern and considerable study. Nitric oxide (NO) emissions may be by far the most serious jet engine emission into the stratosphere, with some calculations indicating that an increase of NO concentration of 30 ppb would reduce the stratospheric ozone concentration by a factor of 2, with consequent profound physiological effects on man and other life forms on earth.

It appears that existing instruments are inadequate to fulfill the needs for determining stratospheric ambient conditions and the effects of jet engine emissions. Sensitivity, accuracy, data rate, and coverage volume should all be improved. A measurement program is needed to provide accurate data on the normal distribution and natural variability of the stratospheric constituents of interest and on the effects of injecting known quantities of jet engine exhaust products into stratospheric regions. This cannot be accomplished without developing improved instrumentation.

Although some improvements in the existing types of instruments can probably be obtained, a technical breakthrough capable of providing really significant improvements is desirable. Recent developments in tunable dye lasers and optical parametric oscillators (OPOs) appear likely to provide the foundation for such a breakthrough. The tunable dye lasers provide signal sources for remote measurements at visible and near-ultraviolet wavelengths, and OPOs provide a similar capability in the infrared. In combination with state-of-the-art optical receivers and data-collection systems, these signal sources offer an optical radar, or lidar, capability for remote, range-resolved measurements of all the stratospheric species of interest.

E. Water Quality

Water use and water pollution considerations are pervasive and apply to almost every aspect of DoD activity. These activities can be categorized for surface waters generally as related to

- Construction, land use, and related fixed facilities
- Hazardous or potentially hazardous military operations
- Weapons and equipment use
- Research and development programs.

These areas were discussed, and several topics for potential advanced research were suggested for each category.

It was pointed out that, in addition to topics requiring advanced research and new technology, attention is required to the nontechnical aspects of water use by the DoD so as to achieve resource conservation as well as to safeguard environmental quality. The potential for DoD leadership in accomplishing more efficient use of water was discussed, and suggestions for further work were offered.

In recognizing the effects of DoD activities on surface waters, it is also important to consider the potential effect of additional activities on ground water quality, from which source most of our water supplies are derived. Many water pollution problems of the DoD are not amenable to conventional treatment because of operational, geographical, or physical constraints. Further, the disposal of especially hazardous liquid or gaseous materials require special attention to guard against adverse environmental effects. The need for advanced research in disposal of liquid wastes by deep well injection and the application of reverse osmosis to waste disposal problems were described to illustrate the future needs in this area.

Another illustration of an important problem area for the DoD is in prevention, recognition, and treatment of oil spills. Past spills from onshore facilities and vessel operations have affected significant areas of the nation's waterways and result in waste of fuels that are in short supply. An important research opportunity would appear to exist in development of rapid means to recognize conditions associated with the imminent release of oil so as to enable the spill to be prevented by positive action. An approach to aerial surveillance is described toward this end. In the event that the spills cannot be prevented, then it is apparent that the spills must be cleaned up. Cleanup of spills from coastal and inland waters entails (1) curtailment of the spilled oil, (2) collection and/or treatment of the oil leading to recovery or dispersal, and (3) restoration of beaches and coastal areas affected by spilled oil washed onshore. The research problem is to provide optimum and efficient means to remove and recover spilled oil with minimum additional disruption to the natural environment so as to facilitate rehabilitation and restoration of affected areas.

F. Materials Handling and Disposal

Significant strides have been made recently in achieving general awareness of the need for rational management of wastes from all sources. Every waste management situation calls for the integrated application of several tactical steps within a unifying strategic concept. It is preferable to avoid waste production whenever practicable; however, it is often neither technically possible nor economically feasible to do so.

Addressing the problem of solid waste management in a positive manner requires identification of elements that result in wastes and assessment of the impacts such wastes represent to man and his environment. Knowledge of waste producing processes is required in sufficient detail so as to concentrate attention on those of exceptional volume, deleterious effect, or geographical extent.

It is no longer possible to make waste management decision solely on the basis of apparent cost. Instead, it is necessary to take into account factors related to natural resources recovery and conservation, as well as considerations of intermedia environmental effects. The steps of waste pretreatment, recycling and reuse, treatment, and ultimate disposal require examination and analysis so as to tailor the techniques to the wastes involved and realize their optimum dispostion. An adequate waste classification and information methodology is needed to identify high priority items for research. Disposal of wastes associated with metal surface treatment operations, lubricants, and explosive manufacture are especially important from the standpoint of the DoD.

Certain wastes are hazardous to the public health because of their chemical, physical, or biological nature, and these require special attention in handling and disposal. Hazardous wastes comprise mainly toxic, flammable, explosive, pathogenic, and radioactive materials. The techniques that may be applied to their management are controlled by the types of waste and the hazard they represent. In addition to proper treatment, principal research needs are in the manner and location of disposal for hazardous materials.

The problems associated with pesticides handling and disposal were separately discussed. Pesticides are important because of their potentially adverse effects on flora and fauna that, if carried to excess, could disturb the ecological balance in sizable areas. The toxicity of pesticides is such that great care is also required in their disposal.

G. Data Management

The success to be achieved in coordination of DoD activities regarding environmental quality is vitally dependent on ready access to environment-related data in keeping abreast of the state of the art and to ensure that DoD components are meeting their requirements with neither excessive overlap nor insufficient cooperation. However, at the present time, there are no coordinated DoD efforts for collection of environmental data or organization of a data base. The most promising solution to this problem appears to be through the use of a data management system that provides for ready access to well-organized environmental information.

Data defining the environmental impact of DoD activities must be identified and assessed in determining if data collection operations will contribute effectively toward meeting DoD directives and regulations. This in itself is no simple matter. One approach for data identification is to structure an Environmental Effects Framework that can be used to link DoD actions with their environmental effects. The framework is developed by tracing the paths of materials through the processes by which they interact with the environment and are ultimately disposed. The main segments of the framework include (1) production-consumption, (2) waste discharge, (3) environmental quality, (4) biological effects, and (5) socioeconomic effects. The framework can serve as the means to formulate approaches to control of environmental effects to achieve desired quality levels. Ideally, the framework can help to achieve a preventive approach to solution of individual problems through availability of sufficient knowledge of cause and effect relationships to permit selection of appropriate control techniques so that unwanted results cannot occur.

In many cases, the basic data to complete the framework will be lacking or incomplete, and environmental monitoring programs will be required. Information regarding (1) measurable parameters of activities, (2) environmental aspects of activities, (3) characteristics of the environment, and (4) standards of environmental quality. Also, demographic and economic information need to be included in the monitoring program so as to complete the description of the environmental effects on adjacent activities.

Finally, the monitoring program, organized to complete the framework and be compatible with it, needs to be tied to a well-designed data management system to accept, store, edit, and disseminate the data collected. The large volume of data anticipated will doubtless require reliance on computer technology. A preliminary description of the design considerations for such a data management system is given, and the possibility of using the existing ARPA network for interchange of environmental data between several data processing centers is discussed as one approach to the problem.

H. Special Problems

Influenced to a great degree by tradition and customs, environmental programs continue to be structured around familiar and important media, particularly air, water, and solid wastes. To these the Environmental Protection Agency, for example, adds noise, pesticides, and radiation. While convenient for many reasons, particularly one of communication, the media approach is not well suited to categorizing a wide variety of potentially interesting environmental research problems. This is often accommodated in many programs by adding a comprehensive category that is intended to include problems not readily described in terms of the more widely recognized media. At best a compromise, this procedure nevertheless is convenient and proved useful during the present study for discussing a number of research areas concerned with indices of environmental quality, total environmental interaction assessment, video communication systems, electronic simulation, radio frequency radiation, noise, and information requirements for environmental impact assessment of weapon development and effects tests.

To comply with existing requirements, it is necessary for federal agencies to evaluate and measure total impact on the environment and to assess progress toward established quality goals. Such information and requirements are expected to become more important in the future. To meet these national requirements, DoD will need to initiate development of an understanding of appropriate indices and indicators of environmental quality and the data needed for establishment and measurement of the indices. Therefore, this problem area implies consideration of not only the standards that must be met and the criteria and objectives needed to formulate the standards but also the monitoring techniques that will be required to provide the necessary data.

Closely associated with the above is the recommendations that DoD undertake a study that utilizes one or more military base or major activity to assess simultaneously all significant resource input flows to the activity, the useful output products of the activity, and the by-product flows and waste effluent from the activity. A total environmental interaction assessment can be made in this manner by the collection and organization of resource, activity, and effluent monitoring data. Using a comprehensive activity-environmental model concept as a guide, the correlations between user activities and environmental effects can be examined. In addition to the above data collection and processing studies, evaluation of models of the sensitivity of military operations to changes in logistic supply and environmental control measures would be useful. The degree to which the models usefully depict observable phenomena and their suitability for inclusion in a comprehensive, empirical, activity-environment interaction model should be evaluated. As a result of the evaluations, promising models or combinations may be used to study the interaction with the environment of one or several bases or activities.

It is interesting to note that certain advanced electronic techniques, which were considered in the past primarily from the point of view of operational efficiency, show promise also in terms of resource conservation and lessened environmental impacts. These include the development of two-way video communication systems and combat training electronic simulation. The first of these takes cognizance of the relationship between video telephone technology (and its complements) and transportation. For such technology, environmental benefits could accrue from reduced need to physically travel, as well as offer new opportunities for land use planning. Additional, and similar, benefits would be expected by increasing substitution of sophisticated electronic simulation techniques for training exercises in the field. Building on simulation techniques currently used for the training of pilots, astronauts, and air traffic controllers, it should be possible to develop an electronic simulation of a training exercise that is no less realistic than present exercises that are also simulations of actual combat. Increased use of electronic simulation techniques might result in significant initial capital costs; but in environmental, material and fuel consumption terms, the cost would appear to be less over the long term. The impacts on air and water quality and noise levels would also be lessened. Ancillary benefits would include the decreased dependence on favorable meteorological conditions and less constraint on geographical location, and the ability to couple the simulation with distant computers would enable refresher training without journey to a special training center. The attendant increase in overall efficiency of DoD in its training activities would surely have favorable implications for resource conservation.

Finally, although the DoD has devoted a considerable effort to the reduction and alleviation of problems associated with radio frequency radiation and noise, additional effort is needed, particularly to more subtle and imperfectly known environmental cause and effect relationships. In the case of radio frequency radiation, it is recommended that present information be expanded to include all existing and planned future transmitters of energy with a view to isolating for further study the transmitter/receiver pairs in which adverse coupling is suspected. In the isolated cases, the susceptibility of the receivers to interference or damage would be further analyzed. Research opportunities concerned with noise reduction are noted with respect to development of fundamental equipment design parameters related to noise, determination of tradeoffs necessary to meet noise abatement requirements, reassignment or retirement of obsolescent aircraft with high noise levels, and evaluation of health related noise exposure standards of the three services to determine if existing interservice and civilian differences are warranted or reflect uncertainty in the current state of knowledge of noise effects.

Weapons testing has never been popular. In earlier days, opposition was based on danger to lives and property. Today, the potential environmental impact of weapons tests is an issue of public conern. In the case of nuclear weapons testing, it is clear that continued underground testing (as in the recent Cannikin event) or a resumption of atmospheric testing will increasingly be circumscribed by environmental factors. As a result, it is necessary to assess the potential environmental impacts of testing programs in advance so that positive programs can be undertaken to minimize adverse effects as an integral part of the testing program.

I. Conclusions and Recommendations

The information summarized above leads to the general conclusion that, in spite of recent progress, much remains to be done in dealing with environmental problems. While further efforts will be needed to address aspects of pollution abatement, control, and treatment, they will be largely remedial; real progress in maintenance and improvement of environmental quality will be achieved only when it becomes possible to eliminate the sources of pollution.

It is apparent that research into a number of environmental problems is required in pursuit of the goal of pollution prevention. This work will need to include both basic and applied research addressed to the several operations and activities that contribute by-product wastes and thereby result in adverse environmental effects. Design of research programs to attack these problems will demand great care, as will the management of resulting data so as to realize their full potential.

Also, it will be important to bear in mind the interrelations of environmental media to guard against "solving" one environmental quality problem by transferring it to a different component of the same environment where resulting effects could be equally serious and undesirable. Conclusions regarding recommended research problem areas are summarized in Table Two-1 according to major headings of the report.

The conclusions expressed in this table indicate the complexity of attempting to identify research targets in regard to environmental topics. Establishing relative priority rankings of the targets is even more difficult, because DoD activities may result in impacts or influences on several environmental media, and existing information is frequently insufficient to determine these effects with precision. Hard choices need to be made: should certain activities that are known or thought to produce pollution be continued while data are sought to define the environmental impact of this pollution, or should action be taken to eliminate apparent pollution even if its actual environmental impact remains to be established? At present, approaches to selecting environmental quality studies for any given topic are often intricate combinations of each extreme in which technical and institutional matters can become confused, with the result that research projects (even if successful) may fail to achieve their intended purpose.

It is clear, however, that advanced research is needed to deal with pressing environmental problems throughout the nation and that a portion of the research budget must be allocated to such projects. To this end, as conditions permit and for the longer term, it may be worthwhile to use a gross ordering of priorities for candidate projects as follows:

(1) Determination of unit environmental impact data by class of activity and media to permit assessment of impacts and evaluation of standards, criteria, and programs intended to achieve environmental quality.

- Examples: environmental impact analysis (Chapter Three, Sections I and II), environmental aspects of resource development (Chapter Four, Section II), development of environmental indices (Chapter Nine, Section I), and air pollution studies on an extended scale (Chapter Five, Section III).

(2) Compilation and evaluation of environmental data to determine environmental effects and analyze intermedia interactions

- Examples: environmental effects framework and environmental monitoring (Chapter Eight, Sections II and III), and total environmental interaction assessment (Chapter Nine, Section II).

(3) Alternative technology to control pollution at its source and conserve resources

- Examples: atmospheric contamination (Chapter Five, Section II), aerial surveillance spill prevention system (Chapter Six, Section III), combat training electronic simulation (Chapter Nine, Section IV), and hazardous waste disposal (Chapter Seven, Section III).

(4) Remedial technology to alleviate problems stemming from previous practices

- Example: oil spill cleanup techniques (Chapter Six, Section IV), noise (Chapter Nine, Section VI), and pesticides (Chapter Seven, Section IV).

Table I-1

SUMMARY OF RESEARCH TOPICS RECOMMENDED FOR CONSIDERATION
by ARPA in ENVIRONMENTAL PROGRAM PLANNING

Environmental Impact Analysis

- Development of logical methodologies and guidelines for analysis of environmental impacts resulting from DoD activities.
- Establishment of methodologies for quantitative evaluation of environmental effects.
- Identification of areas for research to mitigate adverse environmental effects associated with construction activities, hazardous operations, and major defense systems.
- Specific topics for further air quality research were indicated as an example of an output of the methodology.

Resources Management

- Detailed examination of the stages of resource development to identify and specify the unit environmental influence of common commodities used by the DoD according to materials balances for various processes.
- Application of unit environmental data for common materials to assess the impact represented by typical materials, equipment, and facilities used by the DoD.
- Utilization of resource/environmental data to facilitate recognition of means to conserve and reuse critical resources (including technology assessment of new approaches).

Air Quality

- Coordination, cooperation, and participation in current and planned regional air quality studies underway in the civilian sector with particular attention to the EPA Regional Air Pollution Study (RAPS) in the St. Louis region.
- Investigation of potential worldwide climatic changes (global circulation, precipitation patterns, temperature distribution, cloudiness) with respect to releases of pollutants and heat or water vapor.
- Research on the origin and nature of unexpected chemical species in the upper atmosphere, and analysis of the possible consequences of their presence if not naturally occurring
  - Inventory of species or other changes that have been or are being introduced
  - Development of a model to describe atmospheric reactions
  - Final disposition of the products and resulting effects on man and the biosphere.
- Development of an optical radar, or lidar, for remote measurement of the post-launch distribution of hydrogen chloride generated by rocket launches.
- Development of tunable dye lasers and optical parametric oscillators for measurement of the normal distribution and natural variability of stratospheric species and the potential effects of jet engine emissions.

Table I-1 (concluded)

Water Quality

- Inventories of DoD's water using activities, quantities, and types of wastes produced; current system characteristics; and relationships to adjacent civil water treatment and supply systems.
- Assessment of water quality effects from ongoing operations and equipment use.
- Study of effects of DoD operations on ground water quality and on means of applying improved methods to waste treatment and disposal problems.
- Research into techniques to achieve an early warning of the potential for oil spills so as to prevent them; in the event of spills, improved methods for cleanup and rehabilitation of affected areas.

Materials Handling and Disposal

- Study of waste-producing processes to identify amounts, volumes, effects.
- Waste control at munitions installations.
- Development of a waste classification and information methodology for the DoD.
- Assessment of alternatives to the disposal of hazardous wastes.
- Development of improved technology for on site handling, recycling, or disposal of potentially hazardous waste materials.

Data Management

- Assessment of environmental data requirements in terms of a framework that relates diverse environmental effects to their sources (and permits evaluation of their interactions).
- Establishment of an environmental monitoring program to provide essential data regarding environmental factors.
- Design of a data management system to facilitate use of the data for operational and research purposes.

Special Studies

- Development of appropriate indices of environmental quality including consideration of not only the standards that must be met and the criteria and objectives needed to formulate the standards but also the monitoring techniques required to provide the necessary data.
- Development of a total environmental interaction assessment procedure based on data collection and analysis at one or more military bases or major activities.
- Evaluation of advanced electronic techniques for resource conservation and reduced environmental effects, including combat training electronic simulation and two-way video communication systems.
- Investigation of environmental cause/effect relationships relating to radio frequency radiation and noise.
- Development of needed requirements and information for environmental impact assessment of weapon development and effects tests.

CHAPTER THREE--ENVIRONMENTAL IMPACT ANALYSIS

I--DEVELOPMENT OF AN ENVIRONMENTAL IMPACT ANALYSIS METHODOLOGY

I DEVELOPMENT OF AN ENVIRONMENTAL IMPACT ANALYSIS METHODOLOGY

A. The Problem, Study Plan, and Procedures

As required by Executive Order 11507,* the National Environmental Policy Act (NEPA), and other directives, the Department of Defense and other federal agencies have been directing considerable effort and resources to environmental activity. The general experience within DoD concerning these activities is that, although the efforts and actions have shown a steady improvement with time, much still needs to be done to comply with a multitude of regulations, standards, statutory requirements, and other issues related to environmental quality. To this end, there is a continuing need for program review, planning, and development of methodologies that will provide for systematic and uniform responses to needed actions.

1. Study Plan

In cooperation with ARPA, the Office of the Deputy Assistant Secretary of Defense for Environmental Quality, and the Office of the Director of Defense Research and Engineering, the study was organized into several related tasks. They were to:

- Conduct a review of existing DoD Environmental Impact Statements furnished by ARPA to determine the weaknesses of current theory and technology.

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* Executive Order 11507, "Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities" (5 February 1970).

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- Attend selected conferences and symposia on pollution detection, control, and abatement.
- Within the limits of time and funding imposed by the contract, conduct a review of the environmental effects program of DoD components, and other federal agencies.
- Using the information derived from the above three tasks and information obtainable from other sources, identify principal environmental considerations of importance to the DoD.
- Develop a recommended research plan for an advanced research program to be conducted by ARPA.

2. Procedures

At the outset of the first phase of work, consultations were held with ARPA, the Scientific Officer from ONR, and representatives of the Office of the Deputy Assistant Secretary of Defense for Environmental Quality. The primary purpose was to review DoD experience with respect to the preparation of Environmental Impact Statements (EISs) and recommendations as to the manner in which an analysis of these past statements, together with a review of ongoing DoD environmental activities, could be used to identify areas in current theory and technology that represent problems, and thus lead to recommendations for additional research.

Meetings were also held with personnel from the Environmental Offices of the Air Force and the Navy, who provided the study team with copies of a number of EISs. Also, requests were made to the appropriate office of the Army for a listing of Army EISs to be obtained from the National Technical Information Service. Overall, 56 statements were identified as candidates for analysis; 42 were received for analysis. The number of EISs received and those not received are summarized in Table I-1 and detailed by service and title in Appendix A.

Table I-1

SUMMARY OF ENVIRONMENTAL IMPACT STATEMENTS
RECEIVED AND NOT RECEIVED

Service	Number Received	Number Not Received	Total
U.S. Navy	13	3	16
U.S. Air Force	13	6	19
U.S. Army	15	5	20
Defense Supply Agency	1	--	1
Total	42	14	56

B. Analysis of Environmental Impact Statements and Additional Information

Analysis of the 42 impact statements revealed a wide variety of planned actions at a number of locations. When viewed collectively, these diverse statements revealed an interesting and potentially useful pattern, which was organized into several major groupings of activity. Each included types of actions that are similar, as shown in Table I-2. One potential consequence of these similar actions is that they may be amenable to incorporation into single comprehensive statements that cover generic actions should this prove on further examination to be consistent with the requirements of the NEPA. In this approach, which was recommended by the Council on Environmental Quality* and favored by several representatives from each of the services, broad statements characteristic of proposed similar actions are prepared and then detailed for each specific situation and location by the particular service and unit proposing the action.

* Appendix B, AR-57.

Table I-2

SUMMARY OF ENVIRONMENTAL IMPACT STATEMENTS BY TYPE OF ACTION

Action	Number of Statements
Construction, land use, and related activities	
Routine facilities construction	
Related to personnel use (5)	5
Engineering facilities (4)	4
Subtotal	9
Training facilities	
Construction and consolidation (4)	4
Lease to State National Guard (1)	1
Subtotal	5
River channel dredging	1
Electronic systems buffer zone	1
Procurement policies	1
Total construction, land use, and related activities	17
Hazardous or potentially hazardous operations	
Disposal of hazardous materials	
Anticrop agents (3)	3
Antipersonnel agents (5)	5
Subtotal	8
Use of target facilities and training	
Land targets (2)	2
Ship hulls (1)	1
Combat exercises (1)	1
Subtotal	4
Experimental programs	
Cratering experiments (2)	2
Radioactive sensors (1)	1
Subtotal	3
Explosive buffer zones	3
Total hazardous or potentially hazardous operations	18
Development of major defense systems	
Stationary systems	
Electronic installations (2)	2
Missile deployment sites (2)	2
Subtotal	4
Mobile systems	
Strategic bomber (1)	1
Fighter aircraft (2)	2
Subtotal	3
Total development of major defense systems	7

A further usefulness in this type of breakdown is that while all three major categories include problems of DoD-wide interest, the problems identified in the second and third categories (Hazardous Operations and Development of Major Defense Systems, respectively) are more likely to yield research needs that are of interest to, and consistent with, the ARPA mission. This is discussed in subsequent paragraphs, following a brief description of the major action categories.

- Construction, Land Use, and Related Activities--Seventeen actions were identified in this category. They consist primarily of construction and relatively routine training operations. For the most part, the activities are planned to be conducted in close coordination with appropriate local authorities so as to meet established federal and local environmental quality criteria and standards.
- Hazardous or Potentially Hazardous Operations--Although not entirely unique to the DoD, these activities reflect the special requirements of the armed services. The 18 that were analyzed are characterized by needs for significant controls, are usually highly localized and specific, and have high potential for severe environmental impacts if not carefully managed.
- Development of Major Defense Systems--Seven actions were identified in this category. In general, these actions are technologically complex, can have wide-ranging but subtle effects, and in certain situations are subject to both technical and public controversy.

1. Construction, Land Use, and Related Activities

From a research point of view, it would appear that the majority, if not all, of the actions listed in this first grouping require information that is closely related to civilian analogues. These include a broad spectrum of information on wastewater management, air quality control, solid waste management, noise control, and land use planning, including protection and enhancement of aesthetic characteristics. Accordingly, it is current DoD policy to work closely with federal, state, and local agencies in meeting established standards. These activities are extensive and require the expenditure of substantial sums of money, totaling for FY69 through FY73 some 900 projects to control air pollution at 400 installations and about 1100 projects at 570 installations to control water pollution.* Total cost for the period FY68 to FY73 is estimated to be approximately $470 million.

These relatively routine activities are conducted according to established environmental quality regulations and standards and to Executive Order 11507. In particular, the Executive Order is significant since it places a time limit; actions to ensure that air and water quality effects meet existing standards must be complete or under way by 31 December 1972. This has led to a diversity of individual and understandably non-uniform actions. Stated in a different way, the urgency of responding to immediate problems at individual, scattered locations to comply with the deadline has posed a constraint on the development of DoD-wide or even service-wide comprehensive environmental quality management planning programs.

The services have recognized this constraint and are working with the Deputy Assistant Secretary for Environmental Quality and DDRE, Environmental and Life Sciences, to coordinate activities so as to reach established environmental objectives. Problems will inevitably be encountered in changing established practices and procedures as required by the order. Nevertheless, the DoD, by virtue of its mission and organization, is in a favorable position to plan and implement such activities. It would be difficult or impossible for agencies in the civilian sector to plan, prepare, and execute an integrated and nationwide environmental quality program. The DoD has an opportunity to provide leadership in the design of a program that includes research requirements that have strong

* Appendix B, AR-5.

parallels with related civilian research at the federal, state, and local levels so as to aid in making progress in these areas as well.

2. Hazardous or Potentially Hazardous Operations

The Armed Services have discontinued the production of biological and toxic materials and the development and acquisition of biological or toxic weapons or weapon systems that might lead to an offensive capability. Future biological programs will be limited to defensive research such as immunization and safety measures. These actions have necessitated the disposal of large quantities of anticrop and antipersonnel biological agents under controlled conditions to minimize environmental impact. On the basis of the impact statements reviewed, it appears that the disposal methods have been carefully planned in consultation with appropriate authorities. Thus, presuming no new extensive production and stockpiling of biological agents, environmental problems associated with this particular type of activity should be obviated in the future. However, problems of a similar nature will continue and will be concerned with chemical agents and with the use of pesticides, selected herbicides, toxic materials, hazardous materials, propellants, and munitions. Each of the services is addressing these problems, and economies appear to be available using a more coordinated DoD-wide research and development program.

It is clear that training activities that require live munition and realistic targets for surface-to-surface and air to surface training have potential for disturbing local features of the environment. Assuming the necessity for the continuation of such training in the interest of national security, it is apparent that to minimize adverse impacts careful planning is required in making a judicious choice of target locations, in scheduling and frequency of exercises, and in restoration of disturbed areas to permit subsequent use. This will represent a change from past practices that will take time to implement. Although not generally favored in the past over live exercises, improved electronic combat simulation techniques that provide a nondestructive alternative merit further technical study in the light of potential lessened environmental impact (see Chapter Nine). Such methods, some of which have been developed for the space program, are not likely to replace live practice entirely but could provide a valuable supplement to existing training methods.

3. Development of Major Defense Systems

It is convenient to consider development of defense systems in terms of stationary and mobile systems as related to their environmental impacts and related problems. For stationary systems, the impacts extend over a limited geographical range, but in certain cases the use of prospective sophisticated technological systems can lead to highly intense controversy over subtle and imperfectly known environmental cause and effect relationships. This situation is well characterized by the Project Sanguine EIS.* This prospective project represents considerable previous research but remains controversial, primarily over (1) uncertain biological effects of ELF (extra low frequency) radiation and (2) effects of the installation itself on surrounding ecosystems. It seems evident that questions concerning needs for additional research in such areas probably should be placed in the context of advanced DoD planning to decide whether such technologies should be used at all to accomplish mission objectives or whether ELF communications might be used on a wider scale, or instead limited to a relatively few remote locations.

Mobile defense systems such as the strategic bomber, tactical aircraft, and naval vessels interact with the environment on a much larger geographic scale; by virtue of this they can take advantage of the

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* Appendix B, AR-41.

assimilative capacity of the environment for certain impacts. In fact, it is interesting to note that the more important impacts from DoD aircraft are considered to be noise and emissions at testing and operational bases where for practical purposes they may be treated as stationary sources. In recognition of this, current research efforts are directed to emissions reduction and control and noise research, including sound abatement programs for ground operation.

4. Review of Pertinent Activity and Environmental Programs

In addition to the Environmental Impact Statements, other inputs to this phase of study were derived from review of literature about DoD and other agency environmental programs and from meetings and conferences. These information sources are summarized in Appendix B, which lists the 42 EISs received to date and more than 50 additional data sources that range from rather general articles to detailed documents that cover areas of potential significance. Thus the listing provides a useful supplement to the review of EISs, representing the beginning of an information data base of potential utility for DoD environmental quality planning. With respect to comprehensive listings of DoD environmental research activity, the Smithsonian Science Information Exchange recently compiled an environmental research catalog for the Environmental Protection Agency.* Although not intended as a complete collection, the catalog does provide a useful overview of ongoing environmental research, with a total of 5,488 project descriptions that are categorized under air quality, water quality, solid waste management, pesticides, radiation, and noise. Research tasks listed for the DoD are summarized in Table I-3 under the research categories used by the catalog. A more detailed listing is given in Appendix C, which provides a descriptive breakdown of these categories.

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* Appendix B, AR-91.

Table I-3

SUMMARY OF DOD ENVIRONMENTAL RESEARCH TASKS BY RESEARCH AREA

Research Area	Number of Tasks
Air quality	
Emission sources	9
Effects on humans	10
Effects on animals, plants	6
Economic aspects	--
Legal, administrative, social	--
Control methods	17
Measurements	28
Basic research	22
Subtotal	92
Water quality	
Emission sources	25
Pollution identification	22
Water treatment	6
Water management, pollution disposal	43
Waste treatment	47
Pollution effects	12
Subtotal	155
Solid waste management	
Agricultural sources	1
Industrial sources	--
Municipal sources	--
Collection, transportation, disposal	2
Subtotal	3
Pesticides	
Air or water environments	1
Soil environment	1
Adverse effects - plants	8
Adverse effects - man and animals	6
Adverse effects - general	3
Analysis, monitoring, instrumentation	4
Subtotal	23
Radiation	
Sources	7
Effects	67
Measurements	21
Subtotal	95
Noise	
Air transportation	28
Surface transportation	1
Urban and industrial sources	--
Aquatic environment	3
Effects, measurements, equipment	21
Subtotal	53
Total	421

Source: Appendix B, AR-91.

Although the limitations of such listings are numerous, they do give a rather broad measure of DoD activity and concerns with respect to environmental quality research. A major use of the listings and abstracts, as noted by the Environmental Protection Agency, would be to avoid duplication and facilitate communication of ideas, opinions, and data.

C. Methodology for Analysis of Assembled Information

Although the principal aim of research is to solve problems, the choice and statement of a research problem is often more difficult than finding an appropriate solution and in many cases can even define the solution itself. In the area of environmental quality research, a very significant fraction of the problems arises in response to conflicts and controversy. Following this reasoning, many government agencies have attempted to focus on actual or potential conflict situations to structure their activity. However, this approach usually deals in short term situations, and the underlying causes of long term problems remain untreated. To correct this condition, a procedure to facilitate the perception and prediction of potential problems is needed, particularly for activities that are not governed by a set of specified regulations or standards. To address this basic problem, this study has initiated a systematic attempt to develop a logical framework for isolating problems that can be identified as a consequence of DoD activities and from these problems to derive appropriate responses in the form of needed actions, including recommendations for required research.

The methodology is illustrated in Figure I-1 and is described by a series of sequential steps that are noted along the top of the figure and that comprise the following key elements:

- Acquisition, synthesis, and analysis of collected information
- Breakdown of information into categories and subcategories of DoD activity

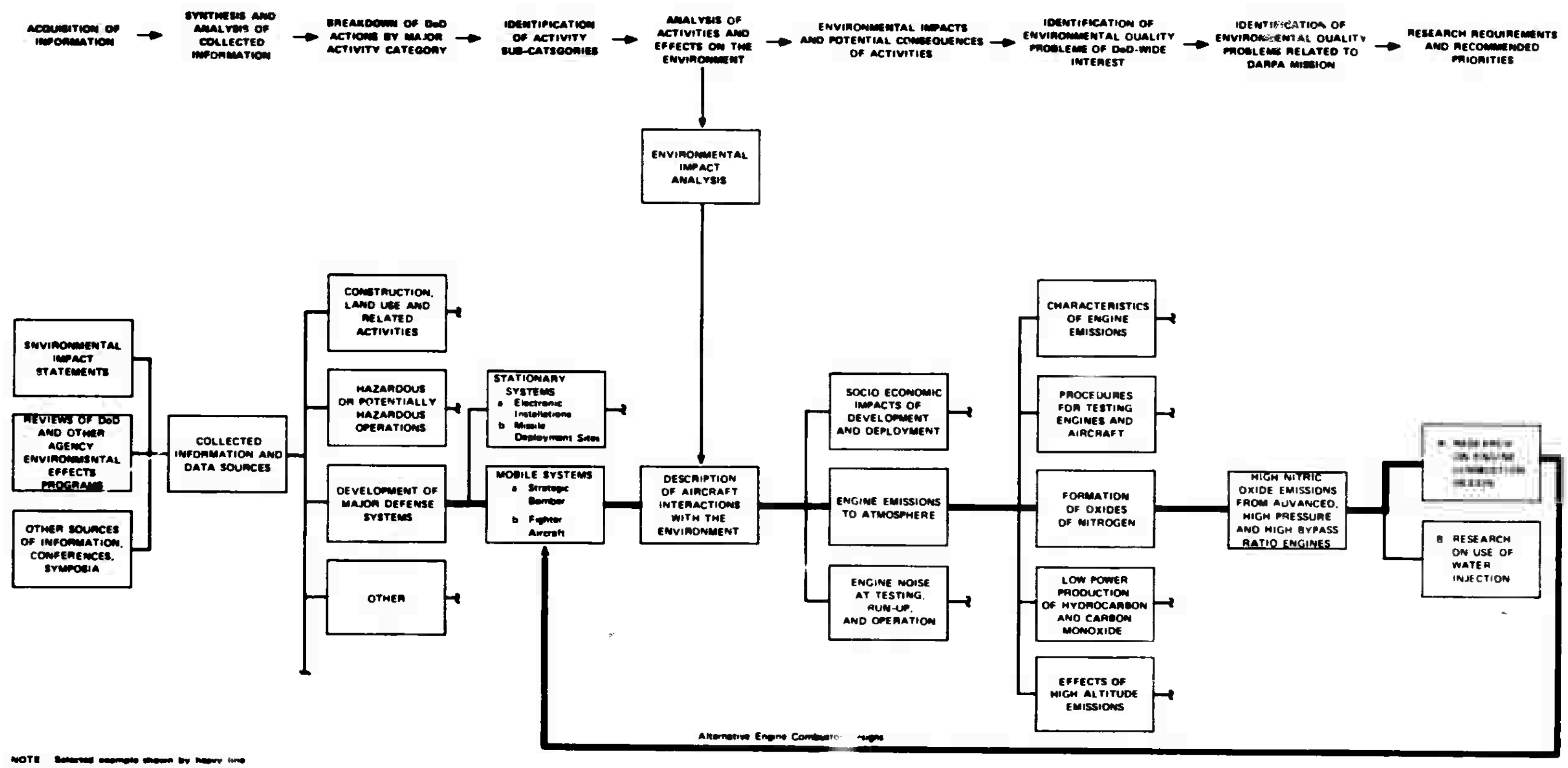

FIGURE I-1 SCHEMATIC REPRESENTATION OF METHODOLOGY FOR IDENTIFICATION OF ENVIRONMENTAL QUALITY PROBLEMS FROM EXAMINATION OF DoD ACTIVITIES AND ENVIRONMENTAL IMPACTS

- Environmental impact analysis based on activities and associated impacts
- Examination of effects of impacts in terms of environmental cause-effect relationships
- Identification of problem areas associated with state of current knowledge concerning environmental effects
- Identification of recommended research directed to problems of interest to ARPA.

D. Acquisition, Synthesis, and Analysis of Collected Information

The data gathering activities described by the first three items of the study plan led to the establishment of a useful, though limited, data base. Although the collected environmental impact documents constitute a potentially useful source of information for structuring DoD activities, their present number, scope, and quality appear to be too restricted for preparing a comprehensive activity analysis. Nevertheless, their future application to this purpose shows considerable promise. Moreover, the environmental impact assessment process necessarily must reflect planned activities, and as consequence a continuing and systematic review of the statements on a DoD-wide basis could provide improved environmental feedback information to the planning process, as required by the National Environmental Policy Act.

E. Breakdown of Information into Categories and Subcategories of DoD Activity

The next steps in the analysis require evaluation of the assembled information in terms of types of actions or activities. In the case illustrated in Figure I-1, the activities are those derived from the environmental impact statements as summarized by the major categories of Table I-2. Again, as an example, the category for defense systems is further subdivided into stationary and mobile systems. At this point, it is readily evident that the number of identified activities would be expected to grow rapidly. On the other hand, the procedure does provide the possibility for combining similar actions. For example, the 42 EISs examined during the study are shown in Table I-2 to be represented by 19 separate actions. As noted earlier, this could be useful for preparing comprehensive statements covering generic actions.

An interesting, and similar, approach to identification of impacts, currently under study by the Army, attempts to translate budget line items into direct impacts on the environment.* For example, the purchase of a truck or tank requires the production of steel, rubber, light metals, electricity, and so forth. A consequence of the latter can be certain types of air, water, and land pollution. The result of such an anslysis encompasses a level of detail that is very comprehensive but thought by the Army to be necessary under NEPA. An illustration of this approach is provided by the draft EIS prepared by the Defense Supply Agency,† which examines certain environmental consequences of coal procurement.

F. Environmental Impact Analysis Based on Activities, Associated Impacts, and Environmental Effects

The next steps in the methodology require a translation of the important DoD activities, or actions, into environmental impacts, thereby aiding recognition of appropriate targets for research. Figure I-1 illustrates how this could lead in aircraft development, for example, to major environmental impacts that are related to noise, engine emissions, and socioeconomic impacts of development and deployment. In turn, the effects of engine emissions, for example, lead to a number of potential problems of possible DoD-wide interest. The formation of nitric oxides

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* Appendix B, AR-89.

† Appendix B, AR-85.

is shown simply to illustrate a problem that could lead to research on engine combustion and thus be fed back to system design or modification.

At the present time, no methods exist for quantitative evaluation of environmental effects, nor is it likely that quantitative methods can be developed to describe all the complicated phenomena that are present. What can and is being done, however, is the establishment of orderly and systematic methods that can provide a high degree of assurance that the majority of impacts are recognized, even if the environmental effects cannot be predicted with certainty. For example, Figure I-1 recognizes the formation and release of nitric oxides to the upper atmosphere from high flying aircraft, but the effects are not known at present. From the point of view of needed research, however, it might be sufficient to note that a problem may exist, and thus a potential research requirement is identified.

Because of the limited time available for the present study, it was not possible to examine in detail the various techniques currently available for translating activities into environmental impacts and effects. To illustrate how this might be done, a moderate effort was expended to the development of methods for identification of atmospheric impacts. The method modifies a cause-effect matrix to reveal whether a methodology exists for quantitatively relating the cause to the effect. The method focuses on cause-effect relationships that theory or observation suggest are important but whose exact relationships are poorly defined. In this approach the primary goal is to identify needs for additional research, but a subsidiary output is the isolation in advance of impacts that may be subject to critical review. A more detailed description is presented in the example described in Section II of this chapter.

For possible future applications, two additional methods were briefly reviewed.

The first method establishes an environmental effects framework* which provides a basis for structuring an environmental predictive capability. The framework is developed by tracking materials through the process by which they are ultimately disposed in the environment and interact with other parts of the environment. The major segments of the framework are (1) production-consumption, (2) waste discharge, (3) environmental quality, (4) biological effects, and (5) socioeconomic impacts. Together with associated interactions that range from input and output factors to impacts on receiving mediums and biological systems, these segments provide for identification of the interrelationship between operations and activities to clarify the resultant environmental effects, as well as for assessment of their possible social consequences. The methodology can also reveal how intervention by actions designed to promote environmental quality can exert influence on operations or activities through the cause-effect relationships to approach a desired environmental quality goal. Furthermore, the methodology can specify the range of data required to characterize the environmental effects--environmental quality management interactions.

Closely related in certain respects is the second method or approach† which develops a model of user-resource interactions. The model represents users that are geographically distributed through an environment and, at a point in time, characterizes both users and natural resources by their relative status: production level and economic conditions for resource users and quantity and quality for natural resources. The model is stepped through time, with each condition and amount being determined at the end of successive intervals. The model may be used simply as a

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* See Chapter Eight, Section II.

† Appendix B, AR-23.

framework for organizing data from both environmental and economic monitoring systems to help correlate resource user activity with environmental impact consequences. The model also may be implemented by a program in which routines are inserted that attempt to represent the industrial economic, physical, and biological processes present. Empirical inputs are central to either application. The output allows the examination in a single model of both environmental and economic consequences of existing or proposed environmental impact control measures.

Each of the above approaches and the atmospheric impact methodology discussed in Section II contain common elements, and, tentatively at least, it would appear that a combination of these elements that are most appropriate to DoD activities will prove to be most useful if developed further. It is readily evident that the techniques, viewed during the present study as a means for identifying research requirements, would also have ready applications by the DoD to environmental impact assessment work.

CHAPTER THREE--ENVIRONMENTAL IMPACT ANALYSIS

II--ANALYTICAL APPROACHES TO IDENTIFYING DOD ENVIRONMENTAL RESEARCH REQUIREMENTS--AN EXAMPLE RELATING TO ATMOSPHERIC IMPACTS

II ANALYTICAL APPROACHES TO IDENTIFYING DoD ENVIRONMENTAL RESEARCH REQUIREMENTS--AN EXAMPLE RELATING TO ATMOSPHERIC IMPACTS

A. Introduction

The analytical process begins with two lists, one of "actions" and one of "impacts." While the lists are being compiled, it is well to remember that every combination of action and impact will have to be considered, and thus the problem emerges as the product of the lengths of the two lists, not simply as the total number of actions and impacts considered.

It is evident that the categories of action and impact must be relatively broad if the problem is to be kept manageable. Not only will it reduce the number of combinations to be considered, but it will also aid in recognizing completed research that is applicable to the problem. Research that clearly connects a broad class of actions to a broad class of impacts will often be recognized when its relation to specific actions and impacts might go unnoticed. For example, the pertinence of research relating the thermal and radiative properties of the earth's surface to the local wind field might go unrecognized if considered only in the narrow context of airfield runway construction.

On the other hand, it is important to use classes of actions and impacts that are sufficiently narrow to actually classify actions so that every conceivable case does not fall into all, or nearly all, the categories. Yet, the classes must not be so specific that each contains only one or two cases. If the categories are selected carefully, then the rest of the problem will be greatly simplified. Furthermore, careful selection of categories will not only aid in the isolation of areas

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requiring research, it will also help define the required research and will be of enormous assistance in the design of a literature search for material that could be used in the preparation of an Environmental Impact Statement. The categories would also provide an organizational framework for a library assembled for EIS preparation purposes.

B. Atmospheric Actions

Because this section is confined to atmospheric effects, the list of actions that is presented includes only items that might have potential impacts on the atmosphere. Since the list has been compiled without specific reference to DoD activities, it should also be applicable to civilian activities.

Specific examples of actions in the various categories also will be presented, drawn from DoD activities and referring to Table I-2 which summarized 42 DoD impact statements. Table II-1 is a partial list of the classes of action that are likely to produce important atmospheric impacts.

In some cases, a particular type of DoD activity may have several aspects that fall into different sections of the Table II-1 list. Furthermore, there may be intermediate steps between the specific activity and the listed categories. For instance, in considering releases of pollutants associated with an activity, there will usually be some requirements for information on the nature of those releases.

1. Releases of Pollutants

a. Ground Level

Examples of ground level releases of pollutants could be drawn from each major category in Table II-1, but the most important cases appear to be related to facilities construction and mobile defense systems.

Table II-1

ACTION CATEGORIES RELATED
TO ATMOSPHERIC IMPACTS

Releases of pollutants
- At ground level
- From elevated sources within the boundary layer (including stacks)
- In the middle or upper troposphere
- In the stratosphere or above

Releases of heat and/or water vapor
- At ground level
- From elevated sources within the boundary layer (including stacks)
- In the middle or upper troposphere
- In the stratosphere or above

Alteration of surface properties
- Radiative
- Thermal
- Roughness

In facilities construction, the problems may closely parallel those facing urban planners, including all the emissions from automobiles, space heating, and other activities associated with groups of people. Large facilities will also have effects beyond their own boundaries. Traffic and housing patterns in the surrounding areas will be changed, and these changes in turn will affect the nature, quantity, and spatial distribution of pollutants released near ground level.

To progress from the description of a proposed facility to a description of the ground level emissions that will result, the facility's effect on the housing, business, and traffic patterns first must be ascertained for the surrounding area. Urban planners and others have studied this aspect of the problem rather extensively, so methods are available for making these forecasts. The next step, which requires that the changed housing, business, and traffic patterns be related to emissions, has also been studied quite extensively, but certain areas will require more information. For instance, models of automotive emissions are not very good for most pollutants, the major exceptions being carbon monoxide and hydrocarbons.

The development and deployment of mobile weapon systems will generally include indirectly the same factors as discussed above for facilities construction. They will also directly contribute pollutant releases to the atmosphere. Airborne (and missile) systems will have such releases during takeoff and landing. Other systems may be analogous to motor vehicles. Although current emission characteristics have been studied for the engines used to propel mobile weapon systems, new studies may be needed to describe the emissions from different propulsion systems or from modifications of existing types.

Other types of DoD activity may also result in important ground level releases of pollutants such as those associated with testing, deployment, and disposal of chemical or biological warfare materials. Target practice and explosive weapons testing will also result in pollutant releases at ground level, but only those associated with nuclear explosives appear to be serious contributors of pollutants. Cessation of atmospheric nuclear testing and extensive past research tend to reduce the requirements for studying the nature of pollutant releases from nuclear weapons, but they do not negate the need altogether.

b. Elevated Sources within the Boundary Layer (Including Stacks)

Defense activities that might produce pollutant releases from elevated stacks again include the construction of facilities. Small facilities might have smokestacks (e.g., incinerators for classified waste). In larger projects, central heating systems or power plants might be required. Unless exotic materials such as herbicides or chemical agents are to be burned, existing technology appears to be adequate to describe the materials likely to be emitted.

Defense systems, both stationary and mobile, may create emissions from stacks, particularly when they require extensive support in the form of electrical power. If existing power plants are expanded or new ones built, then the DoD activity requiring these changes would be likely to result in an action in this category. Furthermore, aircraft takeoffs and landings produce pollutant emissions within the boundary layer.

c. Middle and Upper Troposphere

Pollutant emissions in the middle or upper troposphere will usually be associated with aircraft or missiles and hence, by the categories shown in Table II-1, will be associated with mobile defense systems. The problems of understanding the nature of emissions at higher levels are much the same as those for ground level emissions. However, it may be more difficult to simulate engine operation accurately in the laboratory for the reduced atmospheric pressure and high speed conditions that characterize aircraft operations at altitude.

Another instance of pollutants being released in the troposphere concerns cloud seeding activities of geophysical weapon systems. It might be expected that the characteristics of the released materials in this case will be controlled and known; however, their effects on the environment will need to be ascertained and evaluated.

d. Stratosphere and Above

Many of the sources of pollutants in the stratosphere and above will be the same as for tropospheric releases. There might also be entries related to attempts at ionospheric modification. although, while such activities may have considerable environmental impact, they are beyond the scope of the present discussion.

2. Releases of Heat and Water Vapor

Many processes and activities that release pollutants to the atmosphere also release heat and water vapor. This is because heat and water vapor are two of the three principal products of most combustion processes, carbon dioxide being the third. Combustion processes are also major sources of pollutants, hence the close correlation of pollutant sources with heat and water vapor sources. Emphasis in the following discussion will be on activities that release heat or water vapor without also being major pollutant sources.

a. Ground Level

In addition to the heat and water vapor releases associated with pollutant sources at ground level, heat exchange systems such as used with large electric power plants also belong in this category. Some of these installations use nearby bodies of water for heat exchange, resulting in water vapor transfer from the surface, while others may be more in the category of stack emitted heat and water vapor.

Weather modification is another possible DoD activity that releases heat or water vapor at ground level. Fog modification projects often release large amounts of heat. Another fog dispersal technique uses water droplet seeding from low level aircraft.

Since any action that changes the vegetative cover will alter evapotranspiration, most construction activities will have aspects that can be considered under this heading. In general, construction activities will more often entail removal rather than creation of water vapor sources. Similarly, ground support of mobile weapon systems may require the replacement of areas of evapotranspiration with impervious runways. Filling marshy areas for housing is another example that also removes a water vapor source, as would the use of previously wooded areas as target facilities.

b. Elevated Sources Within the Boundary Layer (Including Stacks)

With the exception of large cooling towers associated with power plants, no examples of elevated emissions of heat or water vapor were found that do not also emit pollutants.

c. Middle and Upper Troposphere

There do not appear to be any important sources that are not associated with pollutants.

d. Stratosphere and Above

This category includes virtually the same activities as were important for pollutant releases. However, it is important to the categorization scheme to separate the heat and water vapor released from pollutants. The reason for the separation should become clearer when impacts of the atmosphere are considered. While some impacts arising from heat and water vapor emissions are closely related to pollutant emissions, it is desirable to consider the others separately.

3. Alteration of Surface Properties

In shifting the emphasis in this discussion to the surface underlying the atmosphere, it is clear that there are problems that are parallel to those of the atmosphere. Thus, by altering the nature of the surface, atmospheric repercussions are likely to occur, and DoD activities that alter the earth's surface characteristics are an important factor in the analysis.

a. Radiative

Construction is the major category of DoD activities that results in changes of surface radiative properties. Replacing a natural surface with building and pavement will change its radiative properties. Even the installation of "natural surfaces" may change the radiative properties--e.g., installation of a golf course in a desert will radically change the emittance and reflectance in the area.

The ground-based facilities associated with certain mobile weapon systems will have aspects that fall in this category of actions. In particular, large runway complexes may have radiative surfaces that are vastly different from the original ground cover that they replace. At the other end of the weapons systems are also changes of the radiative nature of the surface. Bomb blasts, napalm, or defoliation are examples, representing hazardous operations under the heading of "target facilities" or perhaps "hazardous experimental programs."

It may be necessary to quantify the changes in radiative properties that result from DoD activities. Studies of the reflective-absorptive-emissive characteristics of various kinds of surface will be of varying degrees of application and usefulness. Some are too fine in scale, dealing only with very flat uniform surfaces such as seldom exist outside the laboratory. Others deal with larger scale agglomerations of surfaces that may be more typical of mesoscale phenomena such as housing developments and desert acreage.

b. Thermal

DoD activities that alter surface radiative properties will probably also change surface thermal properties. This is certainly true of most construction and land use projects, as well as many support facilities for mobile weapon systems. Weapon system targets will suffer changes in thermal properties, particularly if vegetative or structural cover is destroyed.

The thermal properties of various soils are not well documented, and thermal properties associated with more complex situations such as forests and urban areas are even less thoroughly described. However, as the discussion of action-effect relationships will show, precise quantitative descriptions of the thermal properties are not always necessary to estimate effects with sufficient accuracy for assessment purposes. For example, some empirical relationships are available that do not require detailed inputs.

c. Roughness

The most important changes in surface roughness will probably arise from construction activities where buildings may be added to a reasonably smooth natural surface. Another important change of roughness takes place when wooded or bushy areas are cleared and leveled for aircraft runways.

Surface roughness can probably be described with sufficient accuracy to permit initial assessment so that extensive further research is not necessary. However, specialized applications may require additional work. In general, the surface roughness is of interest because of its effects on atmospheric turbulence and the transfer of pollutants, heat, water vapor, and momentum. Experimental and theoretical studies have provided information on the relationships between roughness and other parameters that is at least as accurate as other aspects of the problem.

Very often, alterations in the surface will cause differences in the way the surface reacts to the atmospheric elements, even though the surface changes may not lead to meteorological changes. For instance, the same amounts of rainfall on surfaces with and without vegetative cover will have quite different results. Although these are not considered as atmospheric phenomena per se, they are related and should be borne in mind.

C. Atmospheric Impacts

The atmospheric impacts considered fall into two general categories. One category is made up of impacts that result in changes in weather elements. This category also includes impacts that alter the constituency of the atmosphere, particularly in ways that are harmful or undesirable. These impacts are more localized in space and time than those in the second category, climatic impacts, which produce changes in weather over long periods of time and large areas, perhaps worldwide. If certain actions produce local, short term weather changes and if those actions are carried out over a wide area or a long period of time, then the results are likely to move to the category of climatic change.

Climatic change can also arise from causes that have little or no local consequences that could be separated from global changes. Changes in the global heat budget would be expected, for example, to change the earth's climate, but the process is fundamentally different from climatic changes that result from a multiplication of local, short term effects.

It should be remembered that individual weather or climatic elements are interrelated. If fog or clouds are produced, they may affect air temperature. Conversely, a rise in low level air temperatures can induce convection, cause cloud formation and perhaps lead to precipitation. Although such secondary effects can occur, they have been largely ignored during these first tentative steps at organizing and analyzing the action-impact problem.

Most of the categories of impact listed in Table II-2 are self explanatory; the discussion that follows clarifies the relationships between actions and impacts.

Table II-2

ATMOSPHERIC IMPACTS

Changes in local weather and climatic elements

- Atmospheric composition, particularly undesirable harmful pollutant concentrations
- Temperature
- Wind
- Precipitation
- Fog
- Visibility

Worldwide climatic change

- Temperature distributions
- Global circulation
- Precipitation patterns
- Other

D. Matrix of Action-Impact Relationships

These actions and impacts provide the foundation for a matrix of relationships among the various classes of each list shown in Figure II-1. Each square represents an action-impact pair. For this analysis, three categories of action-impact pairs will be used. They are:

- Cases where the specified action has little or no relationship to the specified impact, thereby requiring no research to define this nonexistent relationship.
- Action-impact pairs that have a recognizable and perhaps important relationship that has either been defined by past research or is currently being intensively investigated. This category does not represent research program areas in which new DoD participation is thought to be of primary importance.
- Action-impact pairs where the relationships may be important, but the research required to define their nature has not been undertaken previously and is not now currently under way.* DoD research efforts could most profitably be directed within this category. A hierarchy could be established on the basis of the significance of the action category in DoD activities and on the possible severity of the impacts.

Since assignment of the categories is a subjective process, the results presented here are subject to revision and refinement. The very nature of the categories makes them tentative at best. As research programs are undertaken, action-impact relationships first categorized as requiring study will move to the category of those that are understood and defined. Moreover, it is likely that some cases currently considered as unimportant will in the future be considered differently and will have to be moved into the category of those requiring research.

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* A fourth class in this initial stage of study includes cases for which the study team has not been able to determine the state of research in the area represented by a matrix square.

		ACTIONS										
		RELEASE OF POLLUTANTS				RELEASE OF HEAT OR WATER VAPOR				ALTERATION OF SURFACE		
		STRATOSPHERE OR ABOVE	MIDDLE AND UPPER TROPOSPHERE	ELEVATED WITHIN BOUNDARY LAYER	GROUND LEVEL	STRATOSPHERE OR ABOVE	MIDDLE AND UPPER TROPOSPHERE	ELEVATED WITHIN BOUNDARY LAYER	GROUND LEVEL	RADIATIVE	THERMAL	ROUGHNESS
ATMOSPHERIC IMPACT: CHANGES IN LOCAL WEATHER AND CLIMATIC ELEMENTS	ATMOSPHERIC COMPOSITION, PARTICULARLY UNDESIRABLE AND HARMFUL POLLUTANT CONCENTRATIONS											
	TEMPERATURE											
	WIND											
	PRECIPITATION											
	FOG											
	VISIBILITY											
	CLOUDINESS											
WORLDWIDE CLIMATIC CHANGE	GLOBAL CIRCULATION											
	PRECIPITATION PATTERN											
	TEMPERATURE DISTRIBUTION											
	CLOUDINESS											

FIGURE II-1 ACTION-IMPACT MATRIX

In any event, the matrix in Figure II-1 provides a starting point for defining the atmospheric research needs of DoD. The next step is to assign categories to each matrix square. Figure II-2 shows the preliminary classifications that have been assigned. The black squares represent areas where the study team believes that actions and impacts are not sufficiently related to be important. The hatched areas are those where current or past research has been undertaken and DoD efforts are likely to be duplicative. Finally, the open squares show areas that should be considered for DoD research programs.

Although discussion of a matrix of the sort shown in Figure II-1 is loosely based on row-by-row analysis, there will be deviations from this pattern when convenient, or when it seems to clarify the discussion.

Primarily, the first row represents the occurrence of concentrations of pollutants that may be harmful (to humans, livestock, and other animals or materials) or unpleasant, such as odors. In considering these effects, primary concern has been associated with ground level concentrations where the direct effects of pollutants are likely to be felt most heavily. Moreover, increasingly large amounts of air travel make the concentrations at higher altitudes potentially harmful. This factor underlies the need for research expressed by the blank squares in the upper left corner of the matrix. These squares represent the relationships between harmful pollutant concentrations and releases of these pollutants in the upper atmosphere. The first research efforts should be directed at establishing the importance of these relationships. The relatively small amounts of materials released and the required separation distances between aircraft (the principal sources in this region) may mean that people and equipment are not exposed to harmful concentrations.

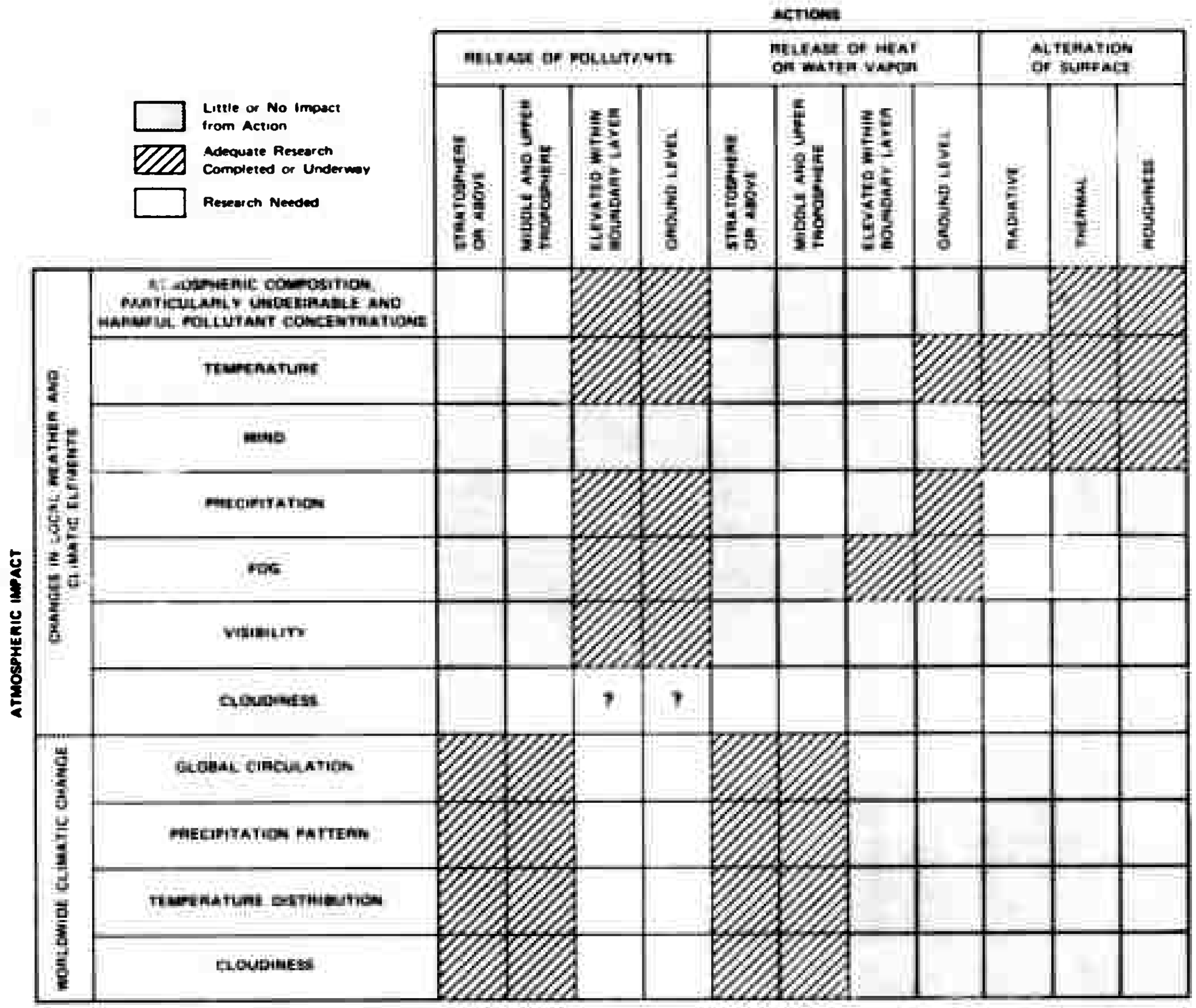

FIGURE II-2 ACTION-IMPACT PAIRINGS

The remaining squares of the first row indicate that DoD research is not required relative to the represented relationships. Many agencies, including the AEC and the EPA, have been and are studying air pollution problems extensively, particularly as related to the behavior of stack plumes and urban emissions. The weakest area is the understanding and modeling of photochemical smog formation processes. However, extensive research programs--theoretical and experimental--are currently under way in this area, and the results of this work should be adaptable to DoD situations.

Since heat and water vapor in reasonable concentrations are not generally considered to be harmful, they are not likely to require research attention with regard to their contribution to the occurrence of pollutant concentrations although they affect composition. Some relationships might be considered, such as high humidities that are damaging to some materials and some chemical reactions involving pollutants that are humidity dependent, but for this discussion they are taken to be of negligible importance.

Also, the effects of surface alteration on pollutant concentrations are of relatively minimal importance, particularly changes in the radiative nature of the surface. Changes in the surface roughness or heat capacity characteristics, under some circumstances, will affect the transport and diffusion of pollutants and hence may have some importance. Studies of urban diffusion have probably supplied sufficient information to treat these effects in as much detail as would be required for most purposes, and these data also will be available to the DoD.

The next six rows of the matrix represent changes of weather or climatic elements on a local scale. Releases of pollutants in the stratosphere are not considered to result in important impacts in this category, because local scale weather is almost entirely a tropospheric phenomenon. Furthermore, interchanges of pollutants between the stratosphere and troposphere generally proceed slowly, so that effects that might occur are more likely to be of a long term, global nature.

Pollutant releases in the troposphere may have effects relating to cloud formation and precipitation. These effects would depend on the ability of the pollutants to initiate or inhibit condensation or freezing. Research in these areas would first be directed to determining the nature of emissions at these levels, principally jet engine exhaust products. If significant amounts of freezing nuclei or cloud condensation nuclei were present, then important effects might result and the next step would be to study the relationships among these materials and ambient meteorological conditions especially as they related to cloudiness and precipitation. A similar course would be followed for substances that might inhibit condensation or freezing. To some extent, Air Force studies directed toward methods of suppressing aircraft condensation trails may have fulfilled these research requirements.

It is highly unlikely that pollutant releases in the middle and upper troposphere would have a direct effect on temperatures and winds. As noted before, the concern is primarily with low level conditions that directly affect the biosphere; the shading shown in Figure II-2 reflects this concern. If temperature and wind conditions at altitude on the local scale are of concern, then some research would probably be desirable.

There will be indirect, low-level effects on temperature and perhaps on wind, arising from changes in cloudiness or precipitation, but the changes in the latter two elements would have to be defined before steps toward understanding low level temperature and wind could be taken.

Visibility has been considered a low level phenomenon and not likely to be greatly affected by material injected into the middle and upper troposphere. However, this meteorological parameter may be important to pilots, and there may be some need for studies to determine the effects of high altitude pollutant releases on high altitude visibility.

The relationships between pollutant emissions and atmospheric temperatures, occurrences of fog, and visibilities can be inferred, to some extent, from studies of urban and rural climatic differences. The relationships and physical mechanisms are not thoroughly understood, but considering the relatively minor magnitude of the effects, the need for further research by DoD does not seem to be urgent. If research were undertaken, fog and visibility would be of higher priority than temperature.

Some statistical evidence exists of pollutant effects on precipitation, a controversial and poorly understood subject. No research by DoD is recommended in this area at this time because the effects are detectable only by rather sophisticated statistical analysis, which indicates that the effects are probably rather small. However, it should be recognized that the difficulties of recognizing the effects are in large part attributable to the natural variability of precipitation, so that even nonnegligible changes are difficult to detect.

Factors concerning the relationships between pollutants and local weather elements also apply to relationships between pollutants and heat or water vapor releases. The similarities in the patterns of black, hatched, and open blocks in the two sections of the matrix are apparent.

It is quite unlikely that sufficient heat is released from most stacks to appreciably affect air temperatures over a very large area. There may be noticeable effects in the immediate vicinity of some of the new, large heat exchangers, but the effects do not seem sufficiently compelling to warrant intensive investigation by DoD at this time. The extensive energy consumption in urban areas may contribute (along with the city's thermal mass) to the urban heat island effect. Since a rather large body of literature exists that describe urban heat islands, there appears to be no pressing need for DoD research along these lines, although it is important to know the contribution from DoD facilities to the adjacent environment.

Even the largest cooling towers appear to be unlikely initiators of precipitation, although this conclusion is admittedly based more on supposition than fact. If DoD activities included very large cooling towers, then some investigation would be warranted. With regard to ground level sources of heat and water vapor and their effects on precipitation, numerous reports of convective activity initiated by large fires are available. However, it seems unlikely that DoD activities would release heat and water in sufficient quantity and frequency to warrant extensive research; should this not be true then further work would be justified.

Fog can be significantly affected by heat and water releases from cooling towers. The formation of fog from cooling tower water vapor releases is of considerable concern in many areas and might well be a high priority research area should DoD build many of these facilities. Changes in fogginess may also result from changes in natural sources of water vapor, such as the filling of swampy areas. Subjective weighing of the effects entailed and the probable frequency of DoD activities that require actions of this sort indicate that currently existing research results and current programs, although few, are probably adequate to satisfy DoD needs in this area.

The effects of high altitude water vapor releases on cloudiness may be very important and deserve attention, although it may be that DoD research on contrails will suffice to define the relationships adequately.

Many of the relationships between surface characteristics and local meteorological factors have been studied, at least indirectly, during investigations of urban meteorology and climate. Some models have been developed to explain the urban heat island, urban air circulations, and the urban mixing layer in terms of the city's roughness and heat capacity. Numerous observational programs have also been reported. Agreement between theory and observation is by no means perfect, but the body of research available should be adequate for estimating environmental impacts related to urbanization. Extending the available theory to apply to surface changes other than urbanization would probably not be too difficult.

Alterations in surface characteristics should have no appreciable effects on visibility accept for those that are connected with fog formation. Since much fog forms through radiative cooling, the radiative and thermal properties of the surface might be expected to exert important influences on the frequency and intensity of radiation fogs. The nature of these influences should be explored. Surface roughness will also affect fogs by induced mechanical turbulence and the mixing of foggy air with warmer air from above the surface, but this appears to be an important factor only in special situations.

It has been suggested that convection, cloud formation, and precipitation might be induced by certain arrangements of absorptive and reflective surfaces. This implies that important changes in cloudiness and precipitation might result from changes in the radiative properties of the surface. The topic requires further investigation.

The remaining set of atmospheric impacts are those of worldwide climatic impact. The hatched and clear areas in the section of the matrix representing the effects of pollutant emissions on global climate reflect the belief that these effects may be very important. The squares relating tropospheric and stratospheric emissions (pollutant, heat and water vapor) to global climate are hatched for one reason only. It is understood that the Department of Transportation (DOT) is undertaking an extensive research program to explore these areas, and therefore it might be a duplication for DoD to enter this area. On the other hand, the questions are so large and so important that more extensive research support may well be warranted to obtain information needed to guide operational programs.

Past research concerning the global effects of pollution--primarily from sources in the lower atmosphere--has raised more interesting questions than it has solved. There is little question that extensive research is needed to relate pollution effects and global climatic change appropriately. To the extent the DoD is an important polluter, its participation in such research is quite warranted and desirable.

All the black squares in the lower right corner of the matrix are predicated on the assumption that it is not currently possible to modify areas of the earth's surface that are sufficiently large so that they will introduce appreciable climatic changes of worldwide scope. This assumption itself deserves some attention. If it is found to be false, then many more important research areas will be added to the list. Similarly, advances in technology may make it necessary to reexamine this assumption periodically. It is quite likely that future technical advances may invalidate this assumption and make it possible to change the earth's surface extensively enough to change climates over a large area.

E. Technological and Other Factors

Although the emphasis in these discussions has been on relationships between actions and impacts, it is clear that the problem does not stop at that point. When adverse impacts are forecast, alternative actions or corrective measures must be considered. In the case of alternative actions, a reevaluation of impacts will be required. For corrective measures, some estimate of their required magnitude must be given. Specifications must be written for the equipment or other corrective methods that are being considered.

Determining the requirements for corrective measures will essentially be the reverse of the problems that have been considered to this point. Viewed in terms of the matrix in Figure II-1, the problem will be entered on the impact side to establish limits on the action side. First, limits of acceptability will be established for a specific impact. For example, federal standards might serve to define harmful concentration levels of pollutants. The next step is to determine the magnitude of the actions that will result in impacts within the specified limits. The blank squares in Figure II-2 show areas where this second step is probably not possible, but the hatched squares represent cases where the necessary specifications for remedial measures can be established.

Once the remedial specifications are established, then another phase of research begins. The existing research data base may be inadequate to develop the technology necessary to meet the specifications that are established. If that is so, then another area of required DoD research is to be pursued. If the required information does exist, then the problem is one of engineering and development. Although this may not be a research problem, it may be as important for DoD to pursue as are the research areas that were discussed.

F. Recommendations for Further Studies

Clearly, additional effort is required to complete the development of methodologies for identifying research requirements. Also, further research in atmospheric impacts of DoD activities is also needed, particularly in the areas described below.

- Releases of pollutants to the middle or upper troposphere and to the stratosphere or above--concentrations and composition.

- Releases of pollutants to the middle or upper troposphere--effects relating to cloud formation and precipitation.

  - Nature of emissions, primarily jet engines

  - Relationships between freezing nuclei or cloud condensation nuclei and emissions.

- High altitude releases of heat and water vapor (middle and upper troposphere, stratosphere)--relationship to cloudiness.

- Alteration of surface radiative and thermal properties--relationship to precipitation and fog formation.

- Worldwide climatic changes (global circulation, precipitation patterns, temperature distribution, cloudiness)--relationship to releases of pollutants and heat or water vapor associated with particular DoD operations.

- Relationships of cloudiness and precipitation to changes in the radiative properties of surfaces.

CHAPTER FOUR--RESOURCES MANAGEMENT

I--RESOURCE MANAGEMENT PROBLEMS--AN OVERVIEW

I RESOURCE MANAGEMENT PROBLEMS: AN OVERVIEW

A. Statement of the Problem

Resources are defined as materials other than air, water, and food that can be used to satisfy a spectrum of social needs. Therefore, the resources considered here are limited to energy and mineral raw materials that occur in the earth. These resources are commonly described as non-renewable, indicating that nature does not replenish them within either the lifetime of man or the span of human experience. The fact that such resources are finite means that development can lead ultimately to exhaustion. Overconsumption or waste in resource use can preempt the heritage of future generations and impair their ability to determine for themselves the role of materials in shaping their response to changing social values. Inefficiencies in resource development and use to achieve relatively short term benefits are of particular concern, since they contribute to potential long term economic problems and result in environmental impacts whose significance is only partially understood.

B. State of the Art

Knowledge of merely the characteristics of such resources is insufficient in meeting the needs of modern society. Resources must be located, developed, produced, and processed into useful form for their true value to be realized. Each stage of the sequence by which resource use is accomplished represents the potential for perturbation of environmental quality; this potential is too often realized in resource development, and numerous examples of adverse environmental impacts are associated with such activities.

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Environmental effects of resource development are related to the state of technology used in such activities. In many cases, basic technology was developed to meet demands for economical resource production without regard for environmental effects from operations. Although some processes may be modified in an attempt to compensate for their environmental impact, it is apparent that new work is required to achieve greater control over these effects. Also, it is not clear that technology developed to satisfy economic demands will be such as to contribute to effective resource management and conservation. For example, a number of processes are based on rather high-grade ores and are less efficient in treatment of the lower grade deposits that are increasingly being developed. This process inefficiency consumes energy, recovers only partial amounts of the resources, and leads to adverse environmental effects. Processes for resource extraction are not alone in this regard, and mining, transportation, and manufacturing operations are in need of similar attention to achieve optimum resource use while maintaining environmental quality.

Briefly, the problem facing the nation is that the use of resources needs to be reassessed in terms of a new set of economic and environmental values that are a departure from traditional institutional and economic patterns. In devising research programs to address this problem, it will be necessary to take a comprehensive approach that establishes a strategic framework allowing maximum benefit from interrelated research. Such research clearly requires the coordinated participation of a number of organizations and agencies, and the role of DoD could be to provide a focus for the work to enhance progress in dealing with this national problem.

C. Present Activities and Organizations

A number of organizations are actively investigating the problems associated with resource management and conservation. The National

Commission on Materials Policy is examining the long range issues in the development of policies to meet the materials requirements of the next 25 years and beyond. The Department of the Interior is responsible for reporting annually "... on the state of the domestic mining, minerals, and mineral reclamation industries, including a statement of the trend in utilization and depletion of these resources..."*

Additionally, numerous domestic government agencies have responsibilities regarding resources, materials, and energy. At the federal level, at least 19 departments and agencies sponsor applied research on materials, 15 are engaged in long range materials policy planning, and 20 have materials information management functions.† This situation is further complicated by the often significant role of regional, state, and local agencies in the energy and resource field; for example, the importance of the Texas Railroad Commission in regulating petroleum production is of national significance. The diversity of agency jurisdications that pertain to energy or resource development is such that knowledge of their organizational procedures and practices are essential to guide related programs in the energy and resource area. Furthermore, attention to the activities of Executive Branch agencies needs to be balanced by knowledge of the duties and jurisdictions of cognizant parts of the Legislative Branch so as to complete the description of the institutional aspects of energy resource development.

The activities of government agencies are extended and complemented by the work of private organizations and institutions in the resource

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* The Mining and Minerals Policy Act of 1970 (PL 91-631).

† See "Toward a National Materials Policy," a report prepared for the Committee on Public Works, United States Senate, April 1969. Reorganization since publication of this report has led to changes in names and locations of some agencies.

field. Industrial firms and their trade associations, as well as universities and other research groups, are important factors in the overall resource posture of the nation.

D. Implications for DoD

The Dod is a priority consumer of materials. As such, it requires advance information regarding the potential character and availability of material resources so as to develop plans to discharge its mission. In a broader sense, however, DoD's materials requirements are such that they influence a significant segment of the industrial economy and thereby have national impact. In short, DoD resource utilization is intimately interrelated with other sectors of the nation, implying the need for a coordinated and cooperative effort in meeting resource needs while achieving progress in environmental protection.

E. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

(1) Monitor current programs relative to definition and development of the available supply of such natural resources currently regarded as vital to the mission of the DoD to determine the character and degree of environmental impacts to be anticipated.

(2) Appraise the environmental effects of present technology for recovery, production, or utilization of resources to determine potentials for enhancing resource conservation.

(3) Assess the present and potential environmental impact of developments of low-grade resources (for which substitutes are unavailable or impractical) at locations and scales not in being at present.

(4) Determine the effect of recycling of materials on deferring the need to develop new sources of virgin materials (both for DoD and for supporting industrial activities).

(5) Determine the influence of DoD equipment or materials specifications on resource availability and environmental impacts from development.

(6) Analyze the environmental impact of the development of naval petroleum and oil shale reserves (when and as necessary) to meet the services' need for fuels in periods of shortages.

(7) Analyze the means to reclaim and rehabilitate lands disturbed from resource development on lands for which DoD is responsible.

Initial comments on several of these areas are presented in the following sections. Section II gives data on the supply-demand relationships for key material resources, while Section III examines environmental aspects of resource development.

CHAPTER FOUR--RESOURCES MANAGEMENT
II--ECONOMIC ASPECTS OF RESOURCE DEVELOPMENT

II ECONOMIC ASPECTS OF RESOURCE DEVELOPMENT

A. Introduction

Nearly every commodity or material produced or used influences the environment in some way. Because of this, the protection and maintenance of a desirable environment mandates serious consideration of materials that have potential major influence on our environment, with respect to both current and future quantities, production and manufacturing methods and alternatives, use, and disposal.

All facets of all major industries should be examined in this context. While the steps of various industries may be classified in several ways, they follow a general pattern of:

- Mining/extraction
- Processing/smelting/refining
- Manufacture/production
- Use/maintenance
- Disposal.

Many steps in some industries potentially can and do influence the environment to a marked degree (e.g., petroleum industry). In other industries, only a few steps result in environmental influence (e.g., cement or glass). A further complication is that one or more steps in some industries are done outside the United States or materials are imported, with the result that the foreign portion of environmental influence may not be readily apparent.

As a result, to determine areas in which care should be taken to maintain a desired environment quality, it will be necessary to examine in detail projected trends of all major industries. This examination should reflect projected quantities of materials and processes that could potentially influence the environment in the future.

To illustrate the type of examination that would be required, the historical and projected supply-demand characteristics of a few nonfuel, resource-based industries are summarized in this section. Factors of production, import, export, supply, consumption, price, reserves, and reserve life index are detailed where the data were applicable to environmental influence. In each instance a summary chart showing supply-demand relationships is given, together with a brief description of factors in a few of the steps that are potential problem areas in environmental control.

The data shown for these industries are not necessarily rigorous or complete. Instead, they illustrate the type of industry information that should be examined in detail. Although these few industries reflect only a small portion of the many industrial, commercial, and residential influences on the environment, they will serve to indicate the significance of each commodity to environment, as well as the magnitude of effort that will be required to determine the major portion of potential future environmental effects. The historical characteristics and projections for these illustrations reflect data primarily from the Bureau of Mines.* In the absence of BOM data, estimates were made from other sources. More accurate projections will be available only after intensive investigation, and in many instances they will differ from the illustrations shown.

For planning purposes, projections are indicated to the year 2000, with estimates of intermediate years of 1980 and 1990. In most instances, projections for the intermediate years reflect constant compound annual

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* Minerals Yearbook, Mineral Facts and Problems, Commodity Data Summaries.

growth rates from 1970 to 2000. However, in some instances, growth rates are expected to change, reflecting modifications in technology, material substitution, alternative process methods, or market changes. For each commodity, it will be necessary to understand and project all factors that exert major influence on supply and demand.

These projections reflect many assumptions, one of which is that imports of materials will continue and even increase. Any change in import/export conditions will necessarily result in changes in projections.

The following commodities that have potentially significant influence on the environment were selected for illustration:

- Aluminum
- Copper
- Iron and steel mill products
- Lead
- Nickel
- Titanium.

B. Aluminum

The aluminum production industry has many problems associated with the control of environmental influences. Solution to the combination of problems will require extensive study of the various processes used and the respective projected demands for each phase of the industry.

The reduction of aluminum metal from its oxide requires large quantities of electrical power for the process pot-lines. As a result, this energy-intensive industry is accompanied by environmental pollution problems inherent in the generation of large quantities of electrical power (e.g., fossil fuel power plant emissions). Pollution problems in the process of aluminum reduction are created by fluorine-containing dust and gases, as well as by waste disposal (e.g., red muds from Bayer plants treating bauxite).[1] These latter problems could become more critical with time. Restoration of mined out open pit areas to usefulness (required in Jamaica) is becoming increasingly important. Subsidance where bauxite was extracted underground may become serious in the future.

The overall supply-demand picture for aluminum in 1968 is summarized in Figure II-1. Sources for world production of 11.130 million short tons are indicated, together with U.S. production, imports, exports, and disposition of U.S. production by use.[2]

Historical statistics and projections for the aluminum industry differ somewhat depending on the source of information. In general, the projections that have been made indicate that aluminum will continue to be a growth industry, with a near doubling of demand between 1970 and 1980 and a further near doubling by 1990. Demand in 2000 is projected to be between a high of 44.4 million short tons and a low of 22.4 million, with a probable demand of 29.7 million short tons (see Table II-1). With a constant annual growth rate of 6.7 percent, the projected demands for 1980 and 1990 become 8.2 million and 15.8 million short tons, respectively (see Figure II-2).

Also included in Table II-1 are aluminum prices, a factor that could influence projected demand with respect to substitution by alternatives; and reserve life index, a factor that could influence primary aluminum production rates.

In contrast to the projected growth in aluminum projection, U.S. mine production is projected to decline to 503,000 short tons of aluminum content in 2000 (see Table II-1). At a constant decline rate, the projected

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[1] Toward A National Materials Policy, The National Commission on Materials Policy, April 1972.

[2] Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.

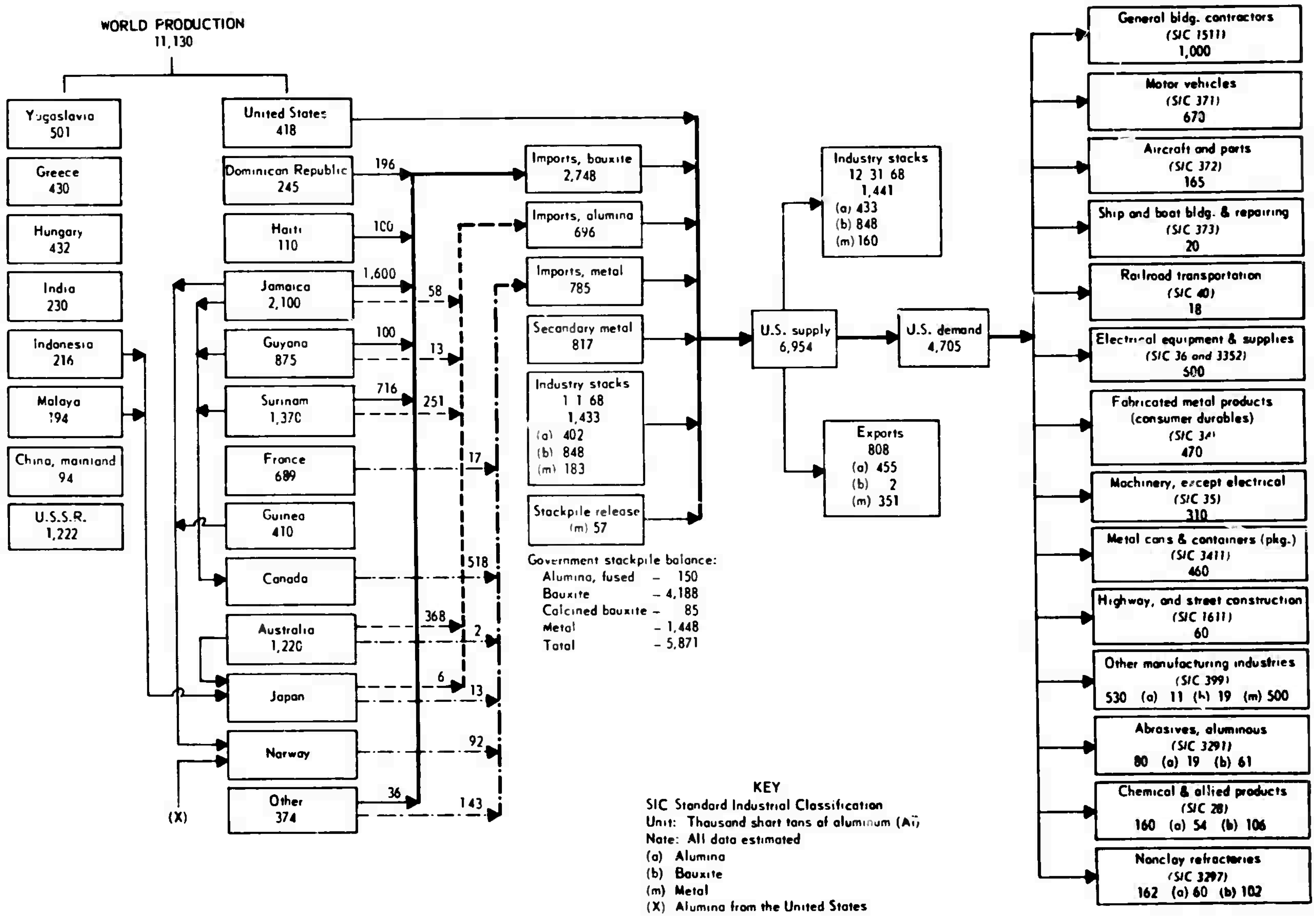


FIGURE II-1 SUPPLY-DEMAND RELATIONSHIPS FOR ALUMINUM, 1968

Table II-1

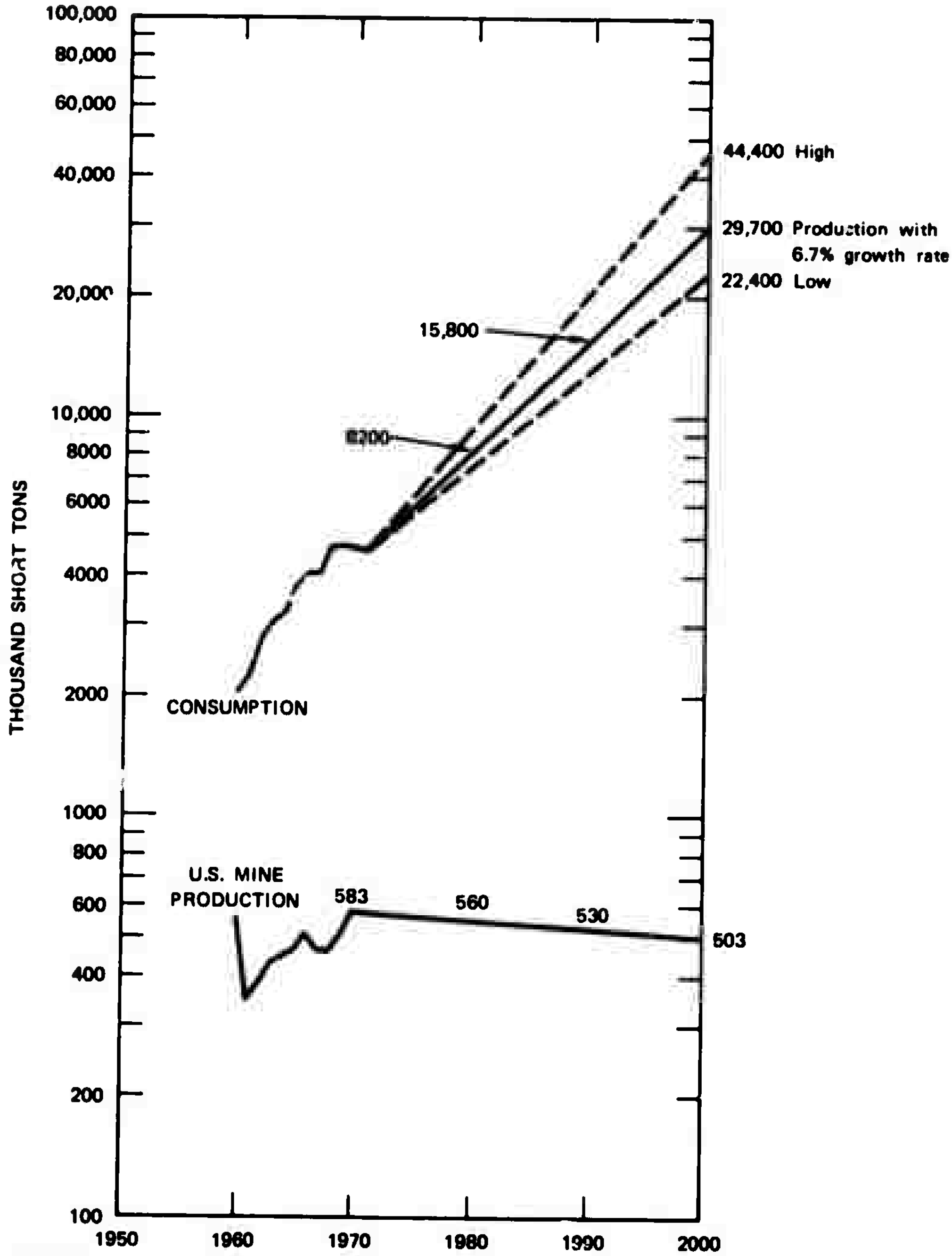
HISTORICAL STATISTICS AND PROJECTIONS FOR ALUMINUM
1960-1971, 1980, and 1990
(Millions of Short Tons)

Year	Production		Imports	Exports	Supply	Consumption	Ingot Price		Price Index	Reserves*					
										United States			Rest of Free World		
	Primary	Secondary					Cents per Pound	Dollars per Short Ton		Mine Production	Reserve	Reserve Life Index	Mine Production	Reserve	Reserve Life Index
Historical															
1960	2.01	.33	.20	.38	2.16	2.02	26.0¢	$520	101						
1961	1.90	.34	.26	.24	2.26	2.32	25.5	510	102						
1962	2.12	.46	.38	.26	2.70	2.77	23.9	478	96						
1963	2.31	.51	.47	.29	3.00	3.04	22.6	452	90						
1964	2.55	.55	.45	.35	3.20	3.22	23.7	474	95						
1965	2.75	.64	.62	.32	3.69	3.73	24.5	490	98						
1966	2.97	.69	.68	.33	4.01	4.00	24.5	490	98						
1967	3.67	.70	.54	.37	4.54	4.01	25.0	500	100						
1968	3.26	.82	.79	.35	4.52	4.66	25.6	512	102						
1969	3.79	.90	.56	.58	4.67	4.72	27.2	544	109						
1970	3.98	.78	.47	.61	4.62	4.71	28.7	574	115						
1971	3.94	.79	.75	.27	5.21	4.60	29.0	580	116	0.583	14.6	25.0	9.1	2,500	275
Projections†															
1980						8.2				0.560					
1990						15.8				0.530					
2000						22.4 to 44.4 (probable 29.7)				0.503					

* Aluminum equivalent.

† Based on annual growth rate of 6.7 percent.

Sources: Minerals Yearbook, Vol. I-II, Bureau of Mines (historical).
Minerals Facts and Problems, Bureau of Mines, 1970 Edition (projections).
Commodity Data Summaries, Bureau of Mines.
Toward A National Materials Policy, The National Commission on Materials Policy, April 1972.



SOURCE: *Towards a National Materials Policy.*
The National Commission on Materials Policy, April 1972.

FIGURE II-2 U.S. ALUMINUM INDUSTRY CHARACTERISTICS mine production would be 560,000 short tons (aluminum content) in 1980 and 530,000 short tons in 1990 (see Figure II-2).

These projections reflect trends in both aluminum production technology and in partial conversion of ores overseas.

Recent developments in aluminum technology apparently indicate increased use of aluminum in automobiles and in the building and construction industries. In addition, the price differential between aluminum and copper for electrical applications favors the use of aluminum as an electrical conductor. An example of the latter is the selection of aluminum transmission cables, which permits lighter cable weight and greater spacing of support towers. The net result is a cost saving for the same electrical current carrying capacity.

During 1970 imports constituted about 89 percent of the U.S. supply of bauxite and alumina. This ore as in previous years came primarily from the Caribbean area and northeastern South America. However, there has been a continuing trend toward converting bauxite to alumina in countries of origin and export alumina to aluminum producing countries. U.S. imports of alumina, largely from Australia, Jamaica, and Surinam, increased 34 percent in 1970, reaching 1.4 million short tons of contained aluminum.

Under conditions of increasing prices, as well as of improved technology, domestic mining can be continued at about 500,000 short tons per year through the year 2000. This is an equivalent supply of about 15 million short tons of aluminum during that interval. This is primarily from reserves of bauxite in Arkansas. Reserves in Alabama and Georgia of about 0.33 million short tons containing aluminum are being mined for specialty uses.

Potential additional domestic resources of bauxite are: (1) large low-grade bauxite clay deposits and deeply buried and thin bauxite deposits in Arkansas, Alabama, and Georgia; (2) ferruginous bauxite deposits in Oregon and Washington; and (3) deposits of low-grade ferruginous bauxite in soils and weathered basalts in Kauai and Maui, Hawaii. Commercial recovery of aluminum from these potential bauxite resources hinges on development of improved mining and processing technology, and increase in aluminum price, or a combination of both factors.

C. Copper

The copper industry also faces many problems with respect to environmental influences. Possibly one of the more pressing problems is the emission of sulfur compounds to the air during smelting. To solve this, new technology and large capital investments will be required to either modify existing practices or adopt new chemical-process techniques.

Additional environmental problems are encountered in secondary copper processing. With limited exceptions, much of the copper used can be reused, making a reserve that is ultimately recoverable. At present, copper scrap supplies about one-fifth of the domestic demand for refined copper. However, only about six-tenths of old scrap, theoretically available for recycle, is actually recovered. Thus the processing systems for recovery and recycle of secondary copper could bear investigation.

Further, the extraction phase of the copper industry is opposed by potentially critical conflicts in land and resource use. Reconciliation is needed in the areas of surface restoration, waste disposal, environmental pollution, and resource utilization. As an example of the latter, about one ton of water is required per ton of ore processed in a concentrator. Because large quantities of ore are processed, corresponding quantities of water are needed, and in areas of limited water supply competition (for domestic needs) results.

The overall picture of the copper industry is illustrated in Figure II-3. This indicates for 1968 a world production of 5.892 million short tons of which 1.205 million was produced by the United States. However, the U.S. demand approximated 2.811 million tons, resulting in significant quantities of imports.

Historical characteristics and projections to 2000 for selected portions of the copper industry are summarized in Table II-2. The projected increase in consumption of refined copper to 6.360 million short tons in 2000 from 2.04 million short tons in 1970 (an increase of about three times) indicates that copper will continue to be a growth industry. However, attention to environmental influence should be directed primarily toward the refining of copper (U.S. mine production is projected to grow only one and one-half times in the same interval).

With a total probable domestic demand of 6.36 million short tons in 2000, a constant rate of increase would result in a demand of 2.90 million and 4.30 million short tons in 1980 and 1990, respectively. This is illustrated in Figure II-4, together with projected primary copper demand and the minimal increase in U.S. mine production.

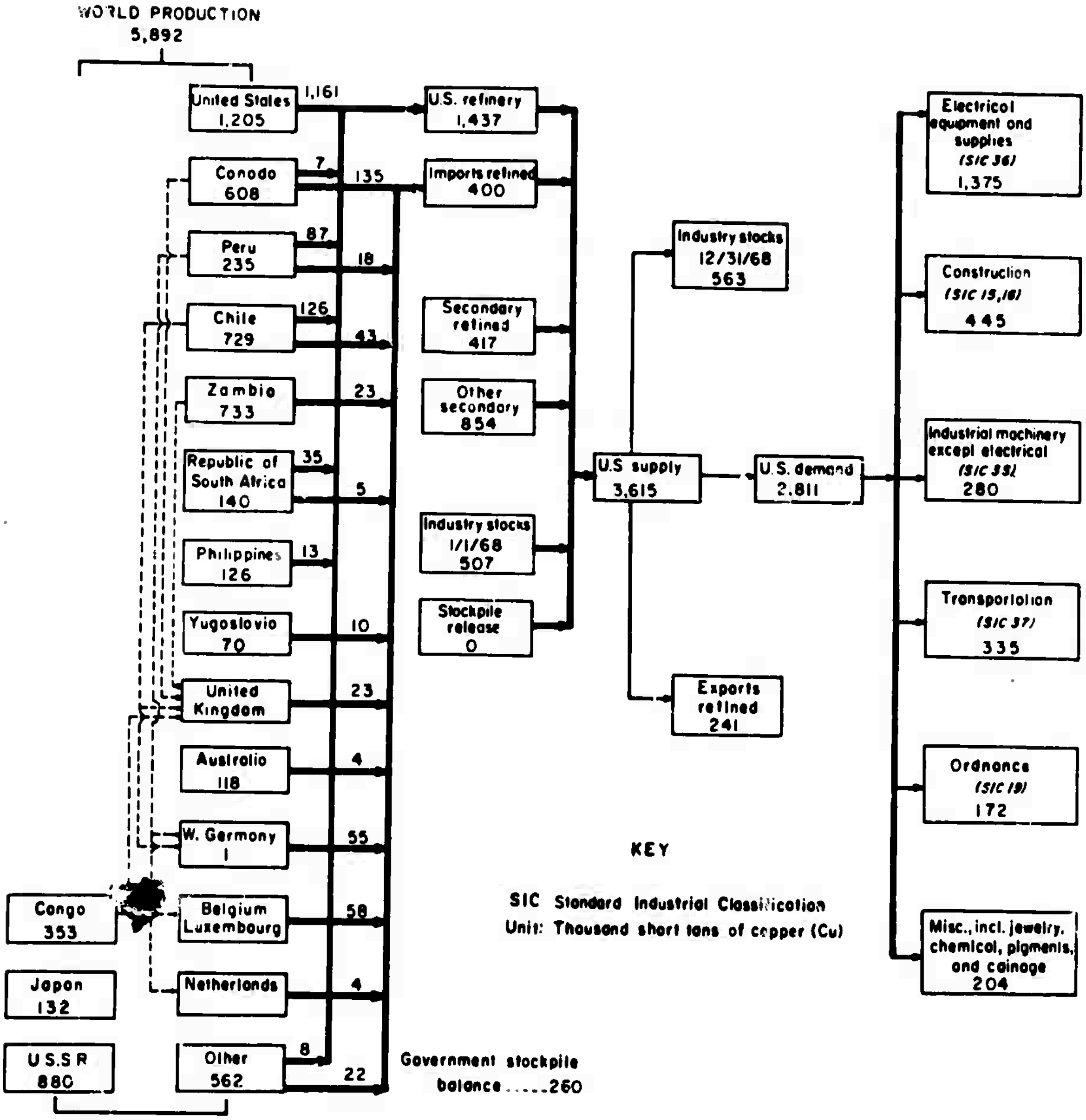


FIGURE II-3 SUPPLY-DEMAND RELATIONSHIPS FOR COPPER, 1968

Table II-2

HISTORICAL STATISTICS AND PROJECTIONS FOR COPPER
1960-1971, 1980, and 1990
(Millions of Short Tons)

Year	Mine Production	Refined Copper		Imports	Exports	Supply	Consumption	Price (cents per pound)	Reserves					
									United States			Other Free World		
		Primary	Secondary				Refined		Mine Production	Reserve	RLI	Mine Production	Reserve	RLI
Historical														
1960	1.08	1.51	.13	.67	.71	1.87	1.35	32.10	1.08					
1961	1.17	1.55	.11	.53	.81	1.68	1.16	30.0	1.17					
1962	1.23	1.61	.42	.58	.70	1.91	1.77	30.8	1.23					
1963	1.21	1.60	.42	.66	.66	2.02	1.85	30.8	1.21					
1964	1.25	1.66	.17	.72	.70	2.15	1.97	32.6	1.25					
1965	1.35	1.71	.51	.66	.70	2.18	2.04	35.1	1.35					
1966	1.13	1.71	.53	.75	.59	2.40	2.13	36.6	1.43					
1967	0.95	1.13	.18	.98	.38	2.21	1.54	38.6	0.95					
1968	1.20	1.11	.52	1.11	.55	2.52	1.88	12.2	1.21					
1969	1.51	1.74	.57	.55	.11	2.12	2.11	47.9	1.51					
1970	1.72	1.77	.51				2.07	58.2	1.72			3.93		
1971	1.53	1.60	.11				2.01	52.1	1.53	81.0	52.9	3.97	219.0	55.2
Projections*														
1980							2.90							
1990							1.30							
2000							6.36		2.38					

* Projections based on annual growth rate of 4.0 percent.

Sources: Commodity Data Summaries, Bureau of Mines.
Minerals Year Book, Bureau of Mines.
Toward A National Materials Policy, The National Commission on Materials Policy, April 1972.

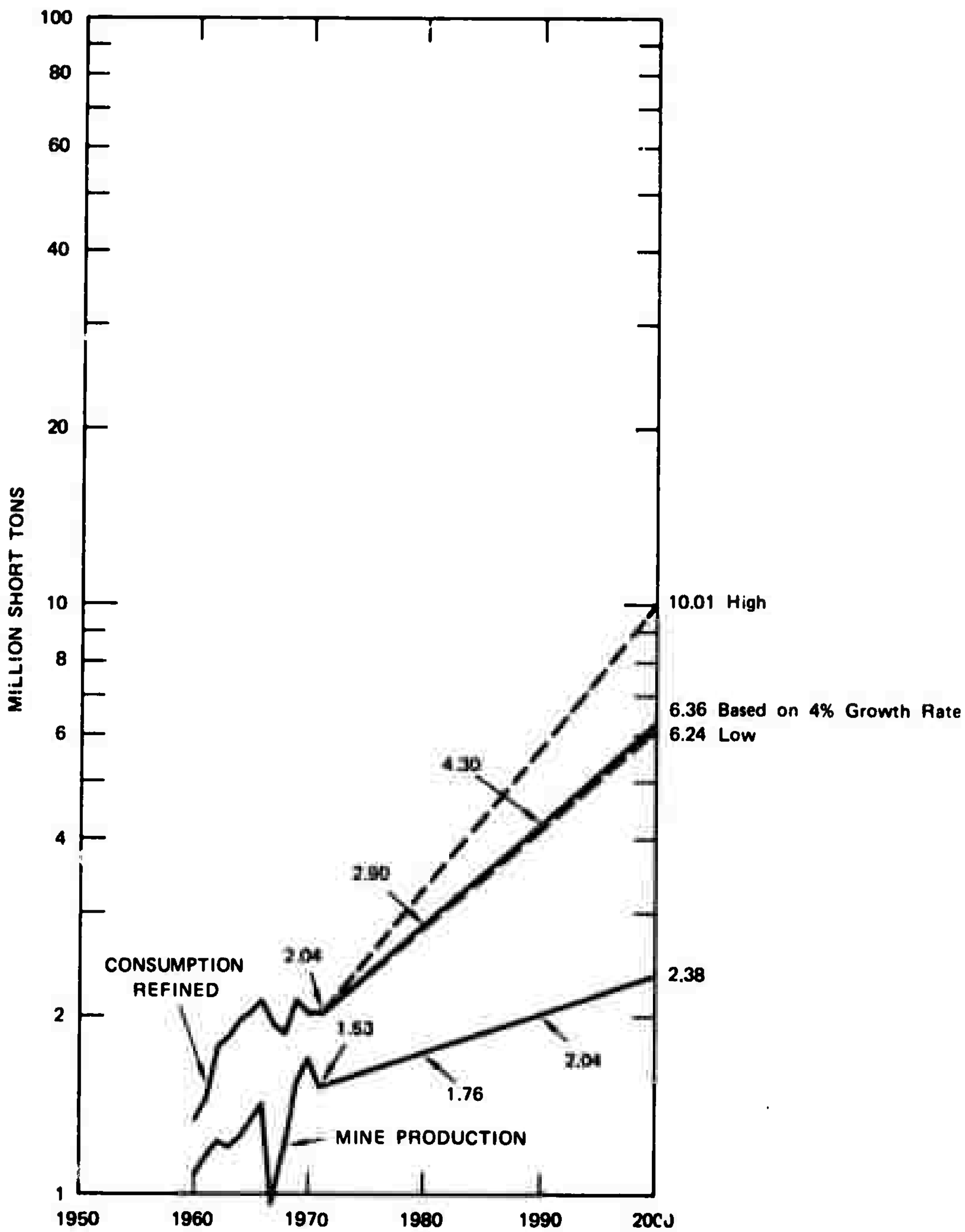


FIGURE II-4 U.S. COPPER INDUSTRY CHARACTERISTICS

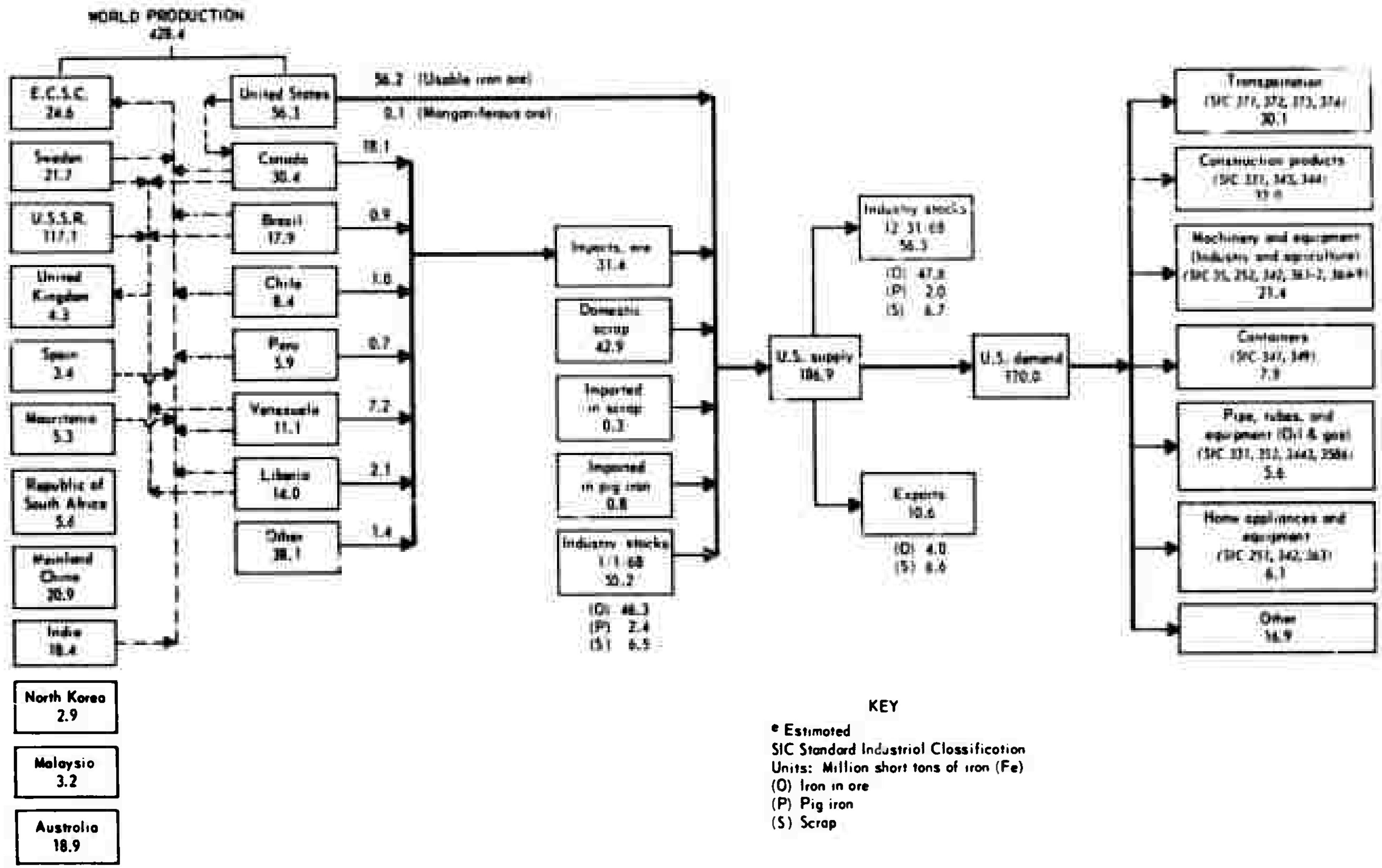
D. Iron and Steel

The overall supply-demand relationships for the iron and steel industry is shown in Figure II-5 for 1968, the latest readily available information, which summarizes sources of ore, imports, process inputs, and product disposition.

Environmental problems are associated with each step of the iron and steel industry, with some of the problems being massive or seemingly unsurmountable economically. The annual production of almost 60 million tons of iron in ore requires the mining or removal of about 380 million tons of material, creating problems in land use, waste disposal, restoration of the landscape, and transportation of ore to the point of use.

Air, water, and waste disposal problems are present in the entire process of iron and steelmaking from ore to finished steel products. Air pollution problems are associated with blast furnace, coke plant and steel melting operations, and captive power plants. Water problems arise from the discharge of large volumes of cooling water and from the disposal of waste products, such as spent liquors and used oil. Solid waste problems include disposal of mine overburden, concentrate tailings, sludges, slags, and dust from air pollution control devices. Scrap processing plants have air and noise pollution as well as aesthetic problems. Even discarded products (cars, tin cans, appliances) pose environmental problems.

The total demand for iron (contained iron) is made up of iron in ore, net imports of steel mill products, and purchased scrap, excluding scrap recirculated in the plant. In 1970, 117 million tons of iron were consumed to produce about 91 million tons of steel mill products and 17 million tons of iron and steel castings. Nearly comparable amounts of iron were consumed in conjunction with the production of 87 million tons of steel mill products and related quantities of iron and steel castings produced in 1971. Imports of finished steel and steel containing products supplemented the volume of domestic primary and secondary iron consumed.



KEY

e Estimated
SIC Standard Industrial Classification
Units: Million short tons of iron (Fe)
(O) Iron in ore
(P) Pig iron
(S) Scrap

FIGURE II-5 SUPPLY-DEMAND RELATIONSHIPS FOR IRON, 1968

Domestic ore supplies about 65 percent of the primary demand for iron, with the balance largely supplied by Canada and Venezuela. About 80 percent of domestic iron ore comes from the Lake Superior district, largely from lower grade taconites concentrated to a high quality pellet and used almost entirely for the production of pig iron or hot metal.

Purchased scrap for steel production supplies about 30 percent of the iron demand. Purchased scrap quantity has been more than was needed, and several million tons were exported in 1970. The iron recovered from the scrap generated in iron and steel production and in consuming plants is of high order, because it is clean and easily segregated from other metals. Obsolete scrap, available from waste and discard, presents the most difficult problems of iron recovery and recycling. However, in a few instances, obsolete scrap from structures and heavy equipment may be recovered easily and sometimes can be reused rather than recycled.

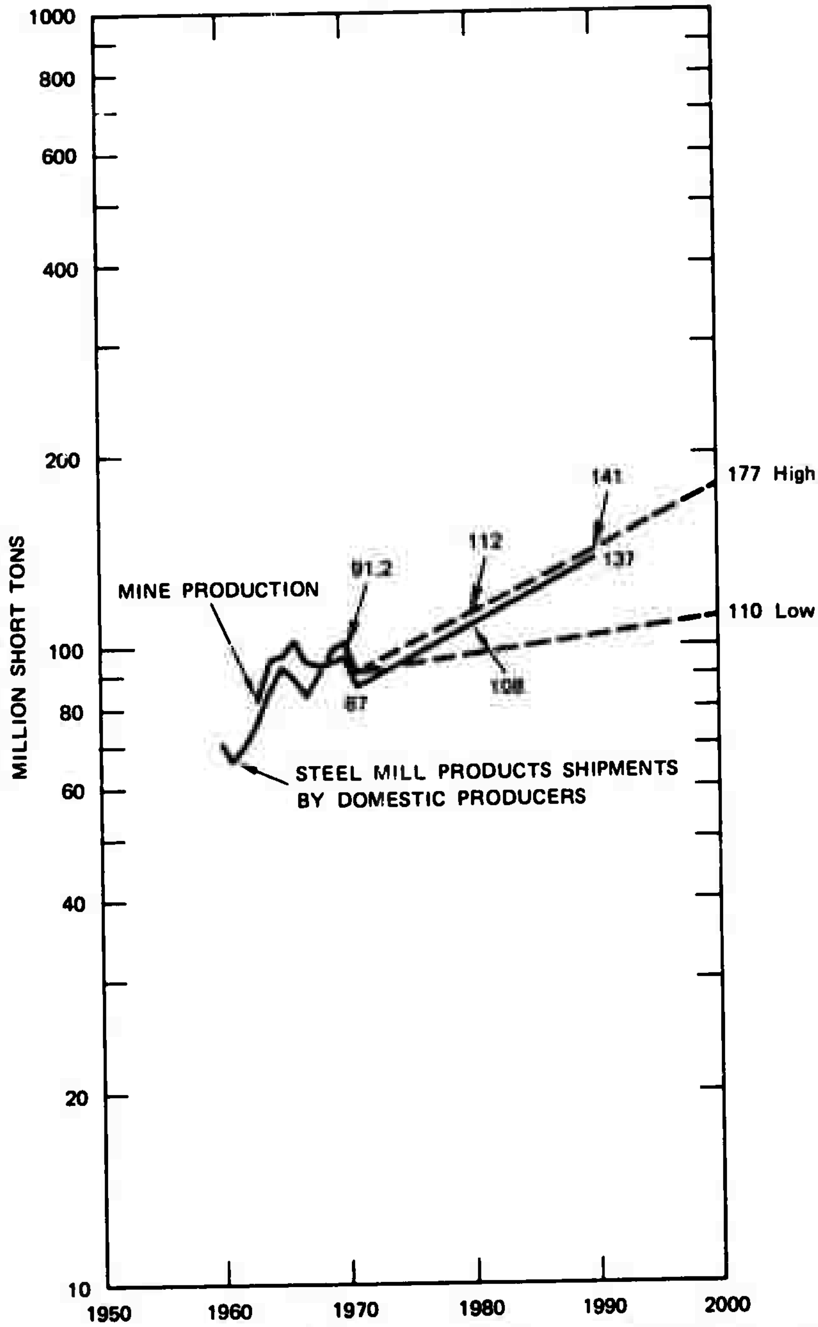
In view of this, the supply-demand relationships of individual parts of the iron and steel industry should be detailed separately. Data for one facet, steel-mill products, is detailed as an example in Table II-3, including shipments, imports, exports, and supply projected to 1990. Also included are historical prices as an indication of a factor that could influence substitution by alternative materials and ore reserve life as an indication of remaining recoverable ore at today's finished product prices. Resulting trends show projected steel mill product shipments at 108 million short tons in 1980 and 137 million short tons in 1990 (see Figure II-6). Projected supply-demand relationships for other parts of the iron and steel industry should be available after detailed research effort.

Table II-3

HISTORICAL STATISTICS AND PROJECTIONS FOR IRON AND STEEL MILL PRODUCTS
1960-1971, 1980, and 1990
(Millions of Short Tons)

Year	Shipments	Imports	Exports	Supply	Finished Steel Composite Price: Cents per Pound	Finished Steel Composite Price: Dollars per Short Ton	Price Index (1967=100)	Steel Mill Production Price Index (1967=100)	Ore Reserves: United States: Mine Production	Ore Reserves: United States: Reserve	Ore Reserves: United States: Reserve Life Index	Ore Reserves: Rest of Free World: Mine Production	Ore Reserves: Rest of Free World: Reserve	Ore Reserves: Rest of Free World: Reserve Life Index
Historical														
1960	71.1	3.4	3.0	71.5	6.196¢	$123.9	95.8	96.4						
1961	66.1	3.2	2.0	67.3	6.196	123.9	95.8	96.0						
1962	70.5	4.1	2.0	72.6	6.196	123.9	95.8	95.8	80.5					
1963	75.6	5.4	2.2	78.8	6.273	125.5	97.1	96.3	82.5					
1964	84.9	6.4	3.4	87.9	6.368	127.4	98.5	97.1	95.0					
1965	92.7	10.4	2.5	100.6	6.368	127.4	98.5	97.5	96.4					
1966	90.0	10.7	1.7	99.0	6.399	128.0	99.0	98.9	101.0					
1967	83.9	11.5	1.7	93.7	6.464	129.3	100.0	100.0	94.3					
1968	91.8	18.0	2.2	107.6	6.600	132.0	102.1	102.5	93.0					
1969	93.9	14.0	5.2	102.7	7.091	141.8	109.7	107.4	98.0					
1970	90.8	13.4	7.1	97.1	7.650	153.0	118.3	114.3	100.5					
1971	87.0	18.3	2.8	102.5	8.429	168.6	130.4	123.0	91.8	2,000	21.8	458.1	60,270	131.6
Projections														
1980	108.0	24.0	2.0	130.0										
1990	137.0	33.0	2.0	168.0										
2000									100-177					

Sources: Annual Statistical Reports, American Iron and Steel Institute.
Iron Age, January 6, 1972.
Commodity Data Summaries, Bureau of Mines.
Stanford Research Institute.



SOURCES: *Annual Statistical Reports*, American Iron and Steel Institute (Historical). Stanford Research Institute (Projection).

FIGURE II-6 U.S. STEEL MILL PRODUCTS SUPPLY

E. Lead

In the lead industry environmental control problems are found in air, water, and land use similar to problems in other metal and mining industries. However, because of previous application of measures to reduce health hazards to employees, concern over environment pollution control may not be as intense as in other metal and mining industries.

The overall summary of the lead industry is illustrated in Figure II-7 for 1968. This indicates that the United States is a major contributor to the world supply--.390 million of the total 3.310 million short tons in that year. However, with the U.S. demand at 1.449 million tons, imports are significant.

Data for historical characteristics and projections for the domestic lead industry differ somewhat depending on the source. Data from the Bureau of Mines are summarized in Table II-4. This source projects the U.S. demand in 2000 to be in the range of 2.52 million to 4.14 million short tons annually with a possible 3.64 million tons, reflecting consideration of many economic factors and trends. These data are illustrated in Figure II-8. Details of projected end use in 2000 are shown in Table II-5.

Comprehensive projections of demand could be available only after extensive investigation.

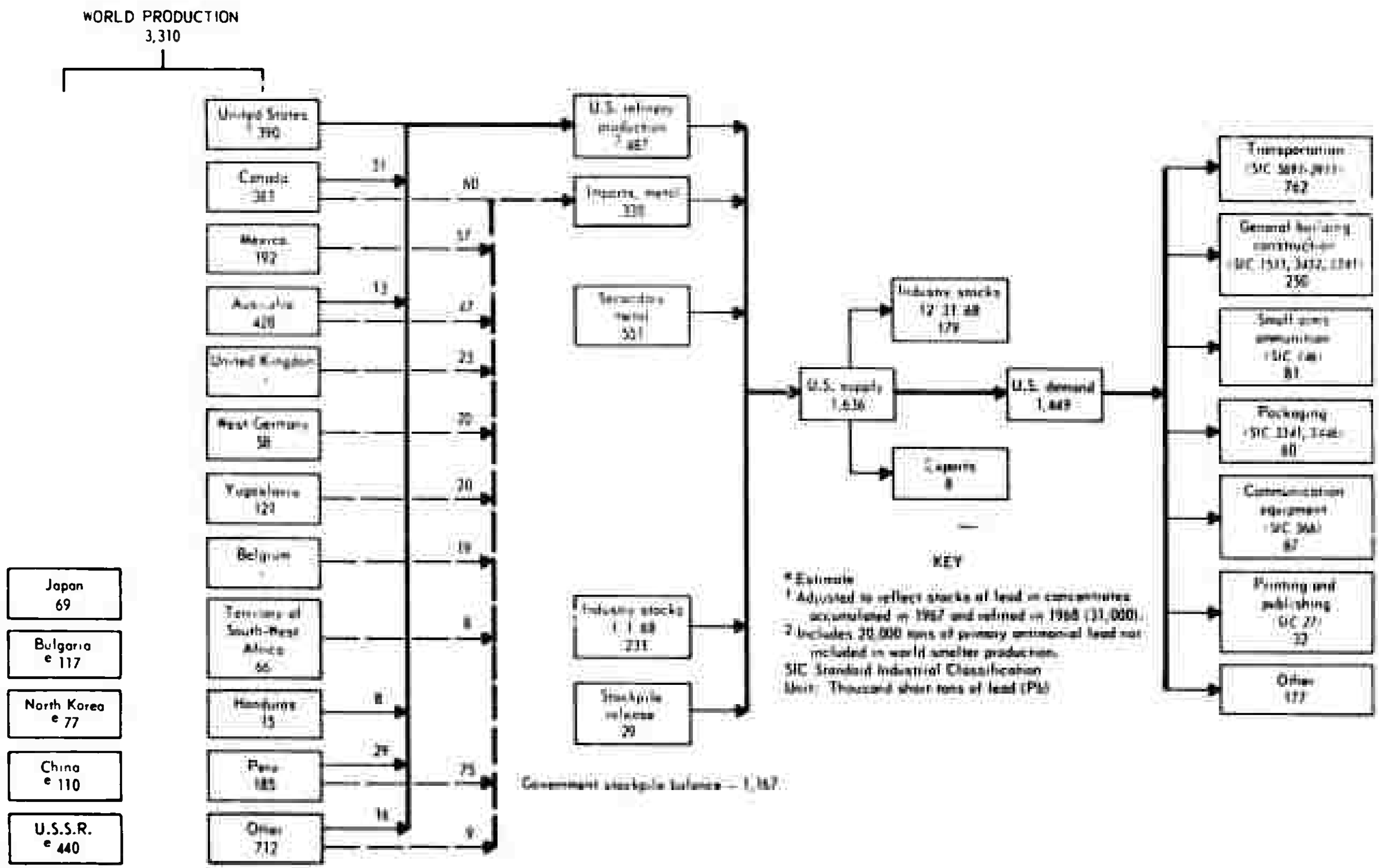


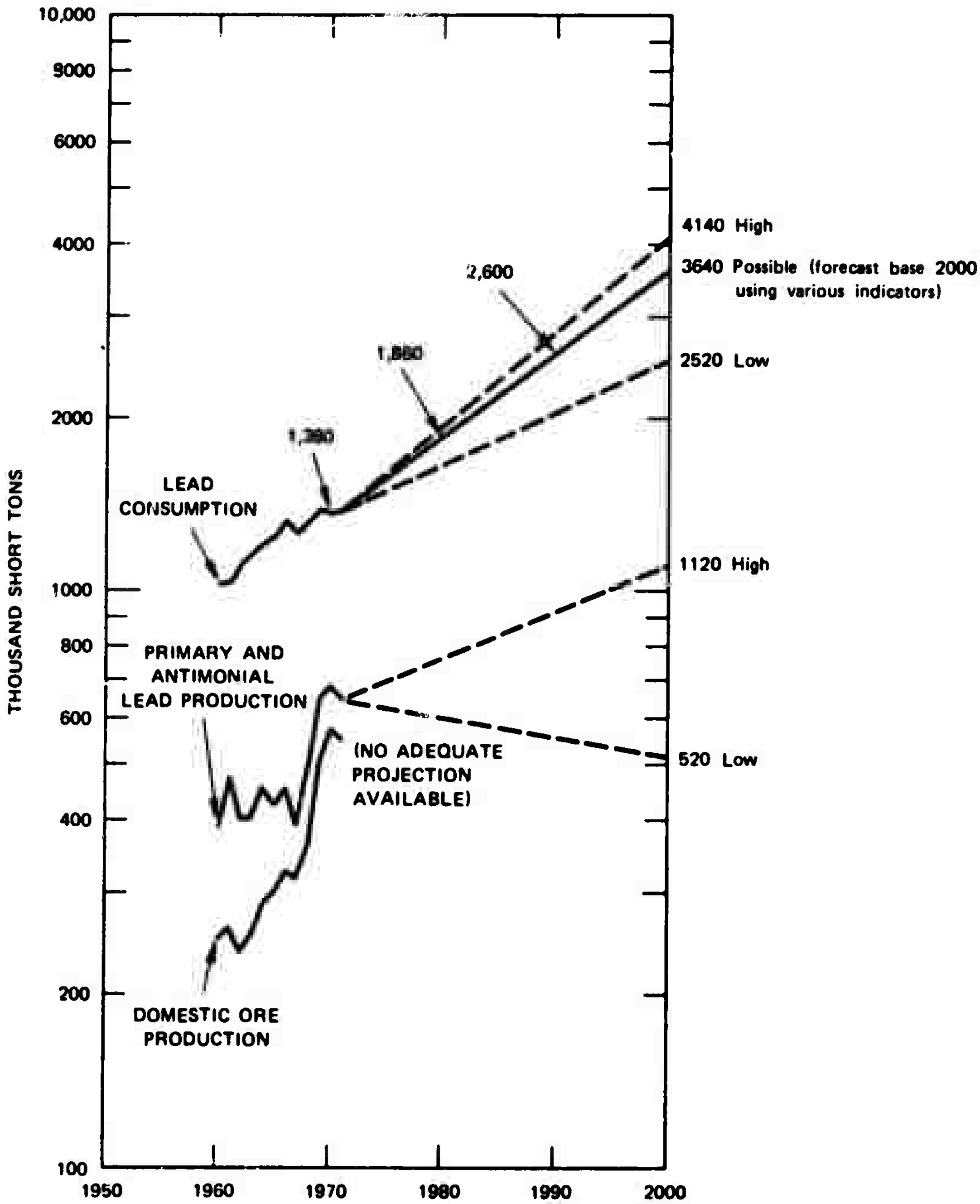
FIGURE II-7 SUPPLY-DEMAND RELATIONSHIPS FOR LEAD, 1968

Table II-4

HISTORICAL STATISTICS AND PROJECTIONS FOR LEAD
1960-1971, 1980, and 1990
(Thousands of Short Tons)

Year	Production			Import	Export	Supply	Consumption	New York Price (cents per pound)	Reserves					
									United States			Free World		
	Primary	Anti-monial	Secondary						Domestic Ore Production (lead content)	Reserve	Reserve Life Index	Production (lead content)	Reserve	Reserve Life Index
Historical														
1960	382	2	470	396	2	1,248	1,021	11.95¢	247					
1961	450	25	453	409	2	1,335	1,027	10.87	261					
1962	376	27	444	403	5	1,245	1,110	9.63	237					
1963	395	9	493	389	1	1,285	1,163	11.11	253					
1964	449	9	542	341	10	1,331	1,202	13.62	286					
1965	418	7	576	350	8	1,343	1,241	16.00	301					
1966	441	11	573	439	5	1,459	1,324	15.12	327					
1967	380	9	554	499	7	1,435	1,261	14.00	317					
1968	467	19	551	432	8	1,461	1,329	13.21	359					
1969	639	16	604	397	5	1,651	1,389	14.93	509					
1970	← 678 →		597	358	12	1,621	1,361	15.7	572					
1971	← 650 →		587	255	15	1,477	1,380	13.8	552	36,000	65.2	2,180	51,000	23.4
Projections														
1980							1,860							
1990							2,500							
2000							2,520 to 4,140 (possible 3,640)							

Sources: Minerals Yearbook, Bureau of Mines (historical).
Minerals Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.
Commodity Data Summaries, Bureau of Mines.



SOURCES: *Minerals Yearbook*, Bureau of Mines.
Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Ed.
Commodity Data Summaries, Bureau of Mines.

FIGURE II-8 U.S. LEAD INDUSTRY CHARACTERISTICS

Table II-5

FORECAST OF DEMAND FOR LEAD BY END USE
(Thousands of Short Tons)

	1968	Forecast Base 2000	United States		Rest of World	
			Low	High	Low	High
Storage batteries	500	1,750	1,500	2,000		
Gasoline additive	262	900		1,300		
Construction/paints	250	400	300	600		
Ammunition	81	130	80	150		
Packaging	60	80	50	80		
Communication equipment	87	80	20	60		
Printing	32	50	20	50		
Others	177	250	150	300		
Total	1,449	3,640	2,120	4,540	4,260	5,310
Adjusted range			2,520	4,140		
Median			3,330		4,785	

Source: Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.

F. Nickel

The supply-demand relationships of nickel in 1968 are summarized in Figure II-9, showing sources of supply and disposition of U.S. production. Primary uses for nickel are in chemical products and in alloys with other metals to improve resistance to corrosion and mechanical and high temperature characteristics.

The United States has relied on foreign imports for most of its nickel materials, and indications are that within a relatively few years (possibly 15) essentially all except secondary nickel supply will be imported. As a result, environmental influences from primary nickel production are not expected to assume major proportions. The only serious pollution problem is the emission of sulfur dioxide during the smelting of nickel sulfide

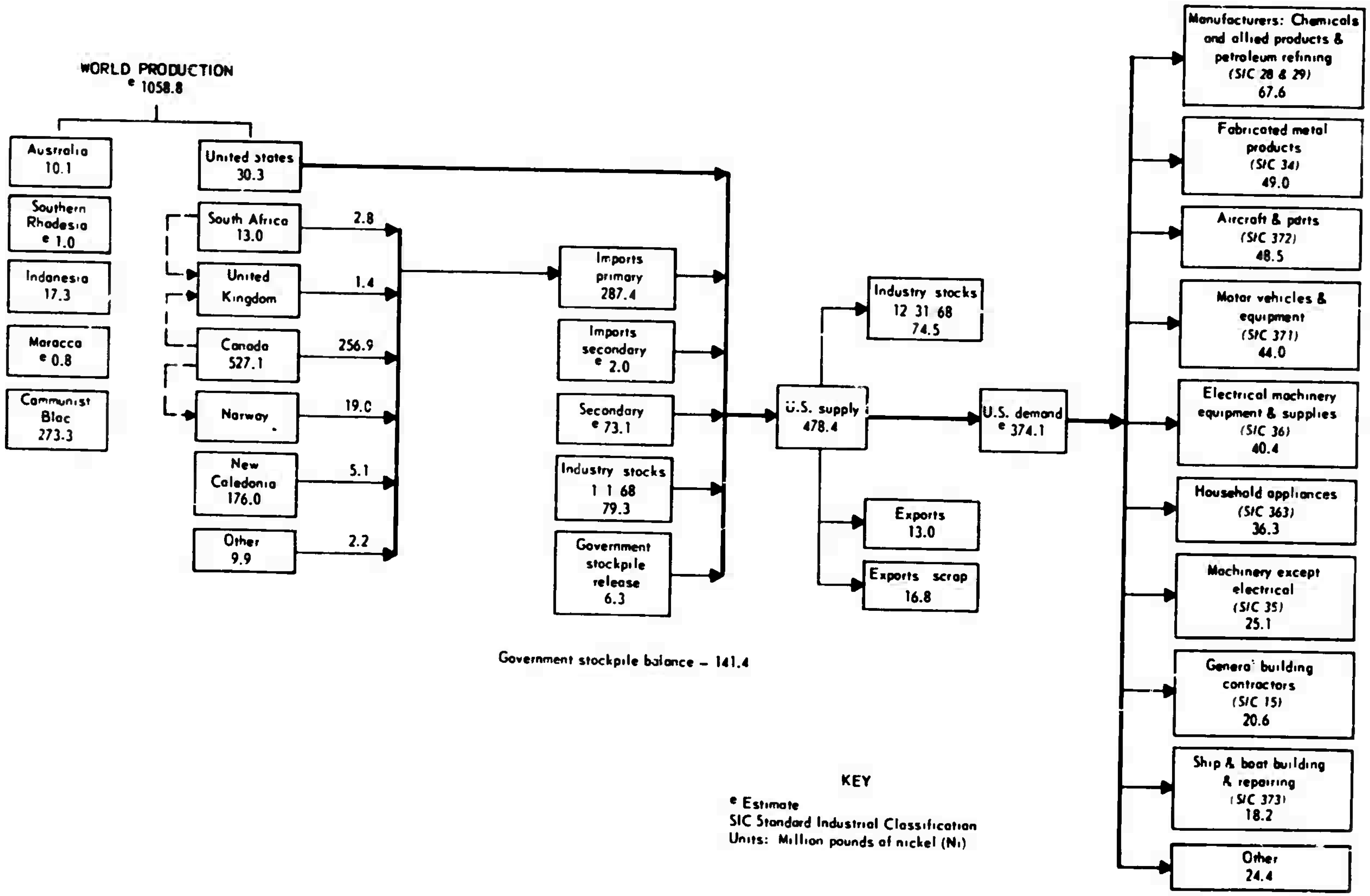


FIGURE II-9 SUPPLY-DEMAND RELATIONSHIPS FOR NICKEL, 1968 ores. Open pit mining of laterites so far has been in tropical areas where vegetation growth can be rapid, with the scars of mining healing quickly, or in areas remote from population.

In many of its uses, nickel is recyclable and recovered by secondary processing (particularly from stainless steels and various nonferrous nickel alloys) where these materials are returned for remelting into the same or similar products. In other nickel uses such as electroplated products, many alloy steels, and cast iron products the low nickel content makes recovery per se technically difficult and uneconomical.

Major problems are associated with the separation of high nickel content alloy scrap from other materials, and sophisticated techniques have been developed to separate, clean, and classify these specialty metals.

Table II-6 summarizes supply-demand characteristics for 1960-71 and indicates the projected consumption for 2000 and intermediate projections to 1980 and 1990. Characteristics shown are primary and secondary production, import, export, supply, and consumption. Additional factors that could influence projections have been included--price, reserves, and reserve life index for the United States and remainder of the free world. It is significant that U.S. mine production is projected to remain at about the current level (about 15,000 to 17,000 short tons of nickel annually) until the reserves recoverable at current prices are exhausted, but the demand for nickel could increase to two and one-half or three times the 1970-71 levels.

The distribution of nickel products by end use for 1968 and the U.S. forecast base for 2000 are detailed in Table II-7. Also shown are the low and high forecasts as projected by the Bureau of Mines. It is significant that although the current major portions of nickel use are in chemical products and in fabricated metals, the largest projected major

Table 11-6

HISTORICAL STATISTICS AND PROJECTIONS FOR NICKEL
1960-1971, 1980, and 1990
(Thousands of Short Tons)

Year	Plant Production		Imports	Exports	Supply	Consumption	Price (cents per pound)	United States			Rest of Free World		
	Primary	Secondary						Reserve	Mine Production	Reserve Life Index	Reserve	Mine Production	Reserve Life Index
Historical													
1960	11.3	9.1	103.0	54.1	72.6	108.2	74¢		14.1				
1961	11.2	10.7	127.0	55.5	93.4	118.5	74-81¼		13.1				
1962	11.2	11.1	123.0	27.6	117.7	118.7	81¼-79		13.1				
1963	11.4	19.0	119.0	60.9	88.5	121.5	79		13.4				
1964	12.2	23.1	129.0	68.5	95.8	146.9	79		15.4				
1965	13.5	19.4	163.0	20.9	175.0	172.1	79-77¾		16.2				
1966	13.2	26.8	111.0	26.4	154.6	187.8	77¾-85¼		15.0				
1967	14.6	20.7	143.0	31.5	146.8	173.8	85¼-94		15.3				
1968	15.2	14.1	148.0	33.7	143.6	159.3	94-103		17.3				
1969	15.6	18.8	129.3	34.8	128.9	141.7	103-128		17.1				
1970	15.3	23.2	136.3	31.5	163.3	155.7	128-133		15.9				
1971	15.5	22.0	145.0	30.0	152.5	130.0	133	200	17.0	58.8	46,000	525.0	87.6
Projections													
1980						201.0			Exhaustion by 1985 at present prices and present production rate				
1990						332.0							
2000						447.5 to 647.5 (possible 548.5)							

Sources: Minerals Year Book, Bureau of Mines (historical).
Mineral Facts and Problems, Bureau of Mines, Bulletin 650, 1970 Edition.
Toward A National Materials Policy, The National Commission on Materials Policy, April 1972.
Commodity Data Summaries, Bureau of Mines.

Table II-7

FORECAST OF DEMAND FOR NICKEL BY END USE

	Estimated 1968		U.S. Forecast Base 2000		Demand in 2000 (millions of pounds)	
	Millions of Pounds	Thousands of Short Tons	Millions of Pounds	Thousands of Short Tons	Low	High
Chemical products	67.6	33.8	256.0	128.0	200.0	275.0
Fabricated metals	49.0	24.5	85.4	42.7	70.0	100.0
Aircraft	48.5	24.3	313.0	156.5	270.0	350.0
Motor vehicles	44.0	22.0	73.2	36.6	60.0	100.0
Electrical equipment	40.4	20.2	160.0	80.0	100.0	180.0
Household supplies	36.3	18.1	60.4	30.2	55.0	70.0
Machinery	25.1	12.6	43.7	21.9	50.0	60.0
Building	20.6	10.3	34.3	17.1	30.0	70.0
Ships	18.2	9.1	30.3	15.2	25.0	40.0
Other	24.4	12.2	40.6	20.3	35.0	50.0
Total	374.1	187.1	1,096.9	548.5	895.0	1,295.0
Short tons					447,500	647,500

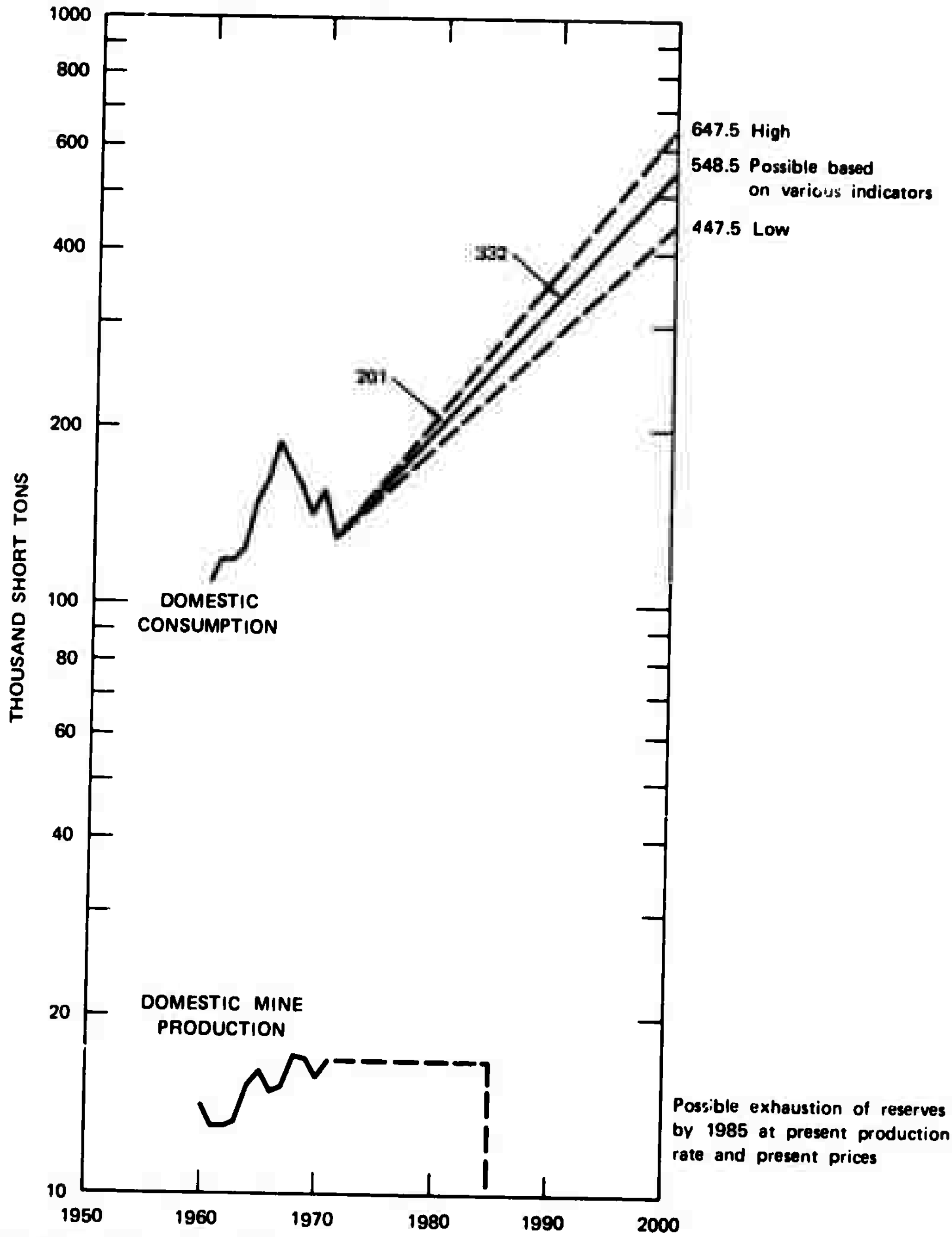
Source: Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.

growth is in aircraft. This reflects projected increased use of light weight, high strength, or special characteristic materials required for maximum stress and high temperature conditions in aircraft operation.

Based on this U.S. forecast base for 2000 and a constant annual growth rate, the projected demand for nickel approximates 201,000 short tons in 1980 and 332,000 short tons in 1990. This is shown in Figure II-10.

Two factors warrant detailed examination of projected nickel use with respect to environmental effects, the rapid growth of nickel in aircraft and the difficulties encountered in separation of nickel in secondary processing.

The future use of aircraft could differ somewhat from current projections. Factors that could slow the rapid development include noise and emission pollution characteristics which could cause economic problems. Conversely, advances in technology credited to aircraft use may prove applicable in other industries and could enhance nickel use (e.g., use of special high temperature characteristics in ground transportation or corrosion resistant alloys in manufacturing equipment).



SOURCES: *Minerals Yearbook*, Bureau of Mines.
Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.
Commodity Data Summaries, Bureau of Mines.

FIGURE II-10 U.S. NICKEL INDUSTRY CHARACTERISTICS

G. Titanium

Environmental influences from the titanium industry stem primarily from the mining and concentrating operations and entail disposal of solid and liquid wastes. While the U.S. titanium industry imports the predominant portion of rutile it consumes, sufficient domestic ilmenite is mined to warrant consideration of disposal of slimes and mud resulting from dredging operations.

The overall picture of the titanium industry is illustrated in Figure II-11 for 1968. This indicates that world production of contained titanium in ilmenite approximates 1.254 million short tons of which the United States produces .305 million. The production of rutile is essentially all foreign, with the United States importing about 103,000 tons (titanium content). The spectrum of product demand of about 458,000 tons is predominantly for paints and other nonmetal uses.

Projected demand distribution in year 2000 is summarized in Table II-8, showing low and high limiting estimates and the projected amount based on various related indicators. This projection indicates that about 92 percent of titanium production will be for nonmetal uses--paints, paper, floor coverings, plastics, and other uses where high opacity characteristics are required. With a constant growth (approximating 4.4 percent annually), the total projected titanium demand in thousands of short tons becomes as shown below in tons.

1968	458
1980	765
1990	1,170
2000	1,797

This is illustrated in Figure II-12.

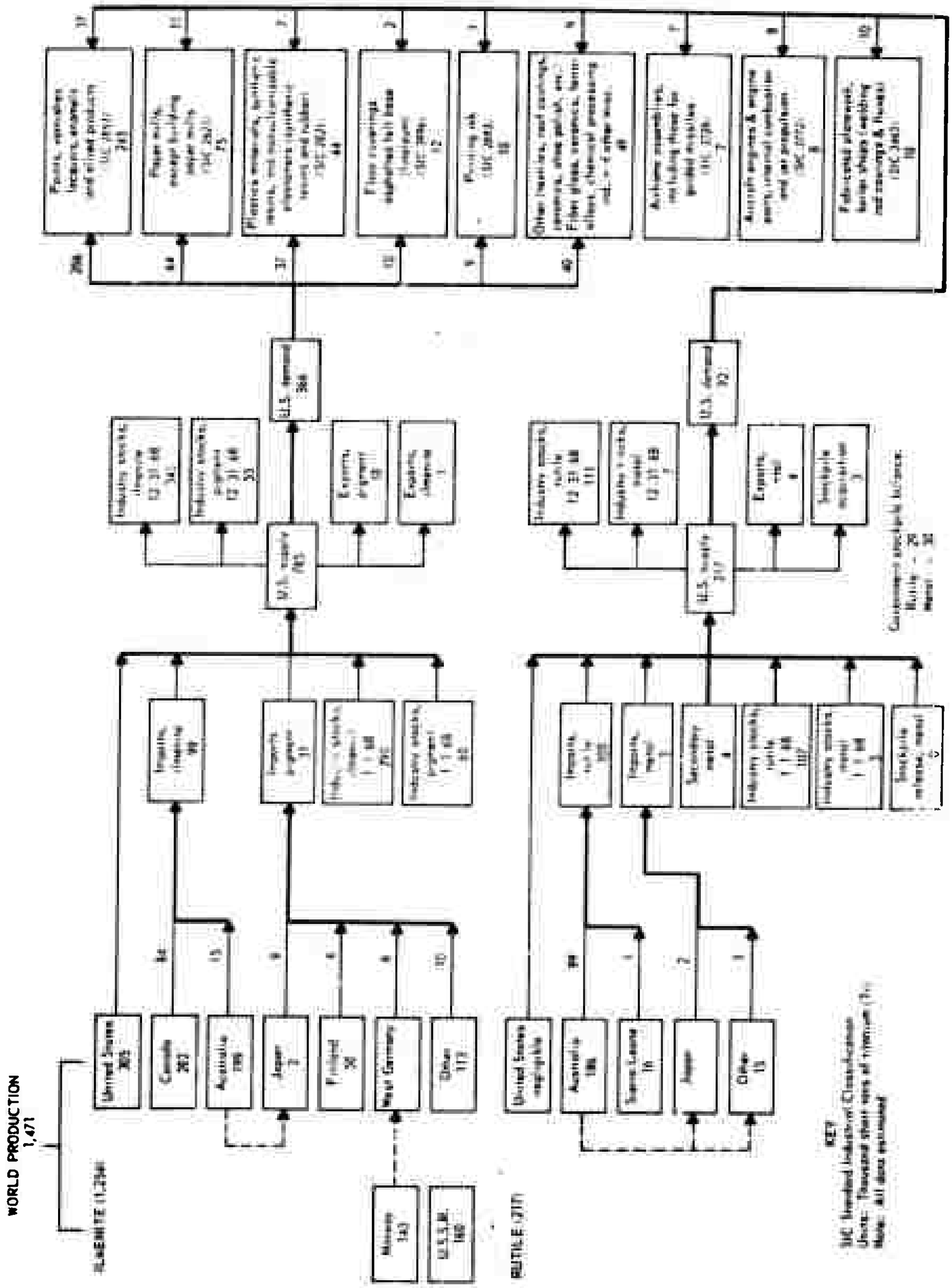


FIGURE II-11 SUPPLY-DEMAND RELATIONSHIPS FOR TITANIUM

Table II-8

U.S. TITANIUM DEMAND FORECAST
(Thousands of Short Tons)

	1968	2000			
		Low	High	Median	Probable*
Nonmetal (primary)					
Paints, etc.	243	500	1,000		980
Paper	75	100	300		260
Floor cover, plastics	56	200	600		200
Other	67	160	260		210
Subtotal	441	960	2,160	1,560	1,650
Metal					
Primary	12.75	62	234		
Secondary	4.25	44	156		
Subtotal	17.00	106	390	248	
Aerospace	15.00	100	340		140
Chemical and other	2.00	5	50		7
Subtotal	17.00	105	390		147
Total					
Primary	453.75	1,022	2,394		
Secondary	4.25	44	156		
Total	458.00	1,066	2,550	1,808	1,797

* U.S. forecast base 2000.

Source: Mineral Factors and Problems, Bureau of Mines Bulletin 650, 1970 Edition.

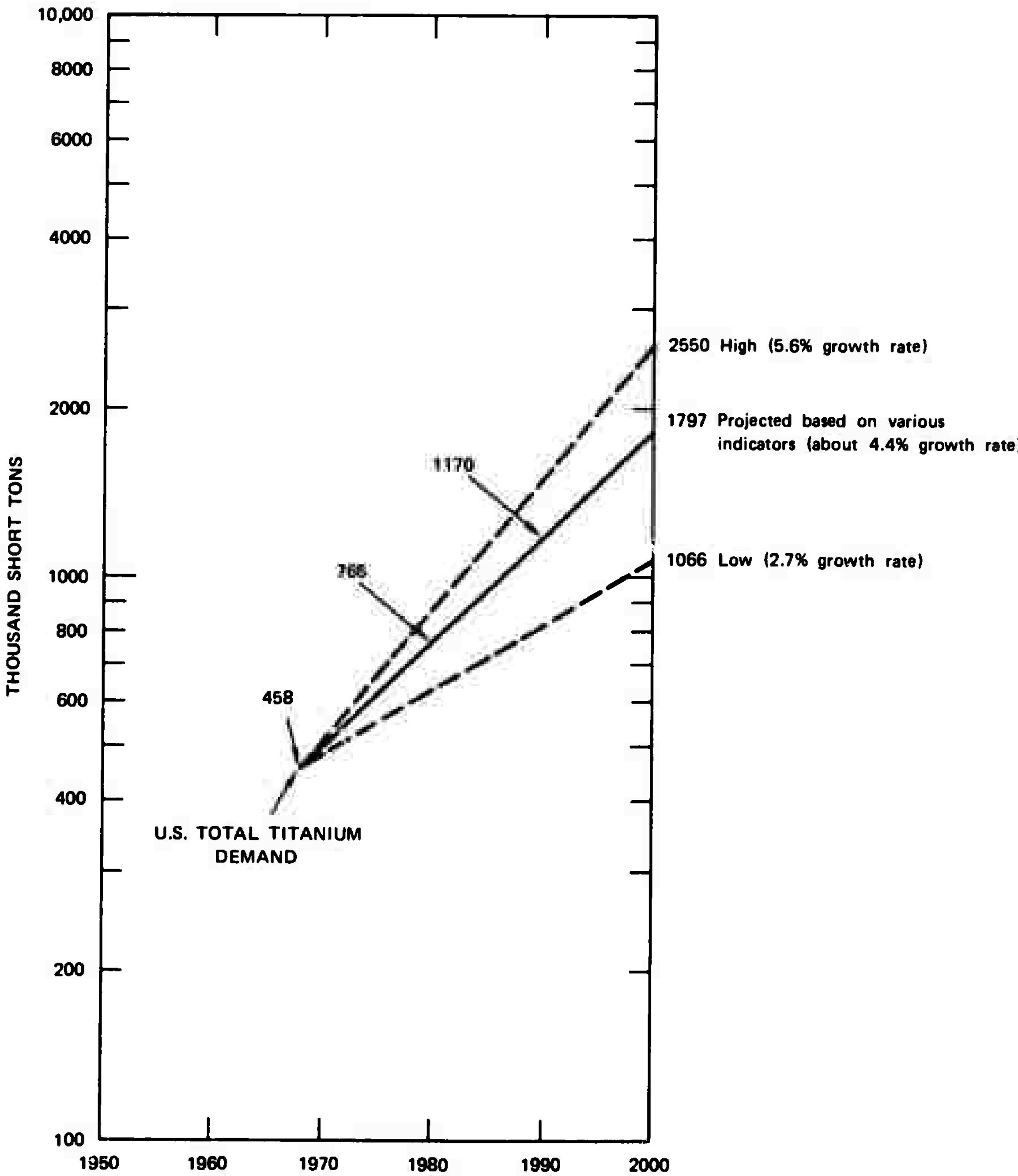


FIGURE II-12 PROJECTED U.S. TITANIUM DEMAND

Because separate parts of titanium processing may exert different environmental influences, historical statistics for each part are summarized in Table II-9. In some instances, data are not available to protect individual company's information when only a limited number are involved. For most of the processing information, detailed projections from proven dependable sources are not currently available. In one part, sponge metal consumption, the Bureau of Mines indicates a range from 51,400 to 184,000 short tons in the year 2000. With a constant growth rate, projections for the intermediate years would be (in thousands of tons of titanium):

	Low	High
1980	19.4	28.8
1990	31.4	72.6
2000	51.4	184.0

This is illustrated in Figure II-13, together with recorded Japanese production.*

World reserves of titanium are summarized in Table II-10. Because recovery of titanium from secondary metal sources is small (1 percent of total demand in 1968), the United States may continue importing rutile from areas of greatest reserves--Australia, and possibly Sierra Leone (if production problems are solved).

* Japan and the United States are the only two major titanium producers in the Free World, the United Kingdom being a distinct third.

Table II-9

HISTORICAL STATISTICS AND PROJECTIONS FOR TITANIUM PROCESSING
1960-1971, 1980, and 1990
(Thousands of Short Tons)

	Ilmenite Concentrate					Rutile Concentrate				Sponge Metal						Ingot		
Year	Mine	Dollars per Short Ton	Import	Consumption	Titanium Slag	Mine	Dollars per Short Ton	Import	Consumption	Production	Import	Export	Consumption	Price (dollars per pound)	Scrap Metal Consumption	Production	Consumption	Net Shipments Mill Products
Historical																		
1960	789	$18.57	266	868	120	9.2	$103.73	29.2	24.2	5.3	2.2	0.9	5.5	$1.60	2.5	8.3	8.0	5.1
1961	783	17.02	207	929	130	7.7	101.51	27.5	29.5	6.7	2.5	0.9	7.0	1.60	2.5	9.4	8.9	5.6
1962	809	17.27	166	945	138	8.0	116.15	36.0	31.7	6.7	0.9	0.8	7.1	1.60	3.2	10.4	9.8	6.5
1963	890	18.57	201	875	152	11.3	111.57	72.0	35.2	7.9	1.5	1.3	8.9	1.60	2.3	11.1	10.5	6.1
1964	1,004	19.10	173	980	128	10.5	96.33	111.0	79.4	n.a.	2.1	1.8	11.1	1.32	2.9	14.0	13.5	7.7
1965	949	19.03	166	923	148	n.a.*	n.a.	152.0	117.0	n.a.	3.1	2.1	12.1	1.32	3.3	15.3	14.7	9.4
1966	868	20.28	187	963	132	n.a.	n.a.	151.0	136.0	n.a.	5.2	1.7	19.7	1.32	4.9	24.3	22.3	14.0
1967	882	20.99	208	919	123	n.a.	n.a.	167.0	153.0	n.a.	7.1	1.4	20.1	1.32	5.8	26.0	25.4	13.6
1968	960	20.29	246	960	112	n.a.	n.a.	174.0	160.0	n.a.	3.4	2.8	14.2	1.32	4.7	19.2	18.3	11.9
1969	893	20.87	317	1,003	139	n.a.	n.a.	205.0	186.0	n.a.	6.3	2.8	20.1	1.32	7.6	28.5	27.1	15.9
1970											6.5	2.9	16.4	1.32				
1971											4.0	1.5	12.5	1.32				
Projections																		
1980													19.4-28.8					
1990													31.4-72.6					
2000													51.4-184.0					

* n.a. = not available.

Sources: Minerals Yearbook, Bureau of Mines.
Commodity Data Summaries, Bureau of Mines.
Toward A National Materials Policy, The National Commissinn on Materials Policy, April 1972.

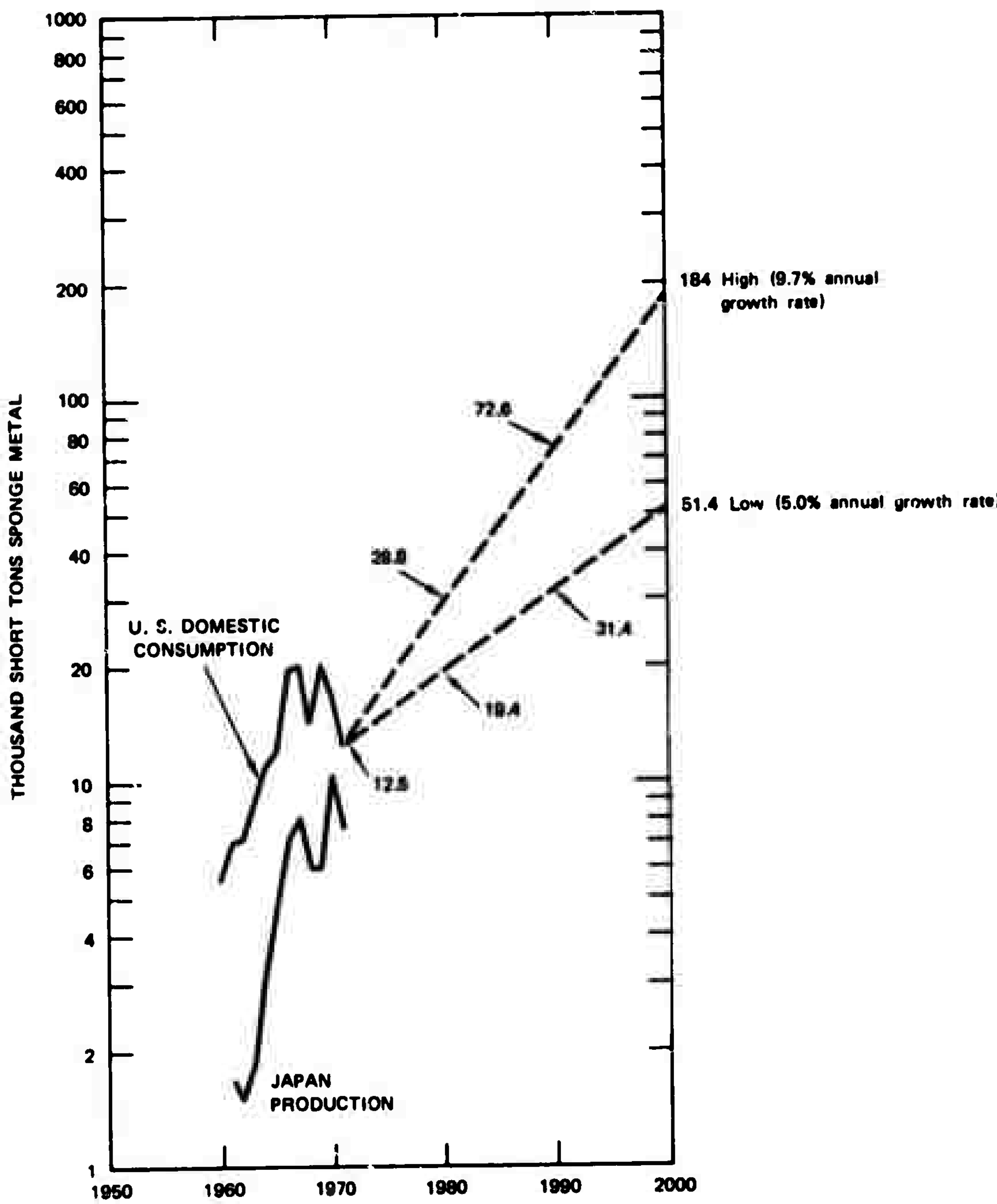


FIGURE II-13 TITANIUM SPONGE METAL STATISTICS

Table II-10

TITANIUM: ESTIMATED RESERVES
OF ILMENITE AND RUTILE
(Thousands of Short Tons)

	Ilmenite	Titanium Equivalent	Rutile	Titanium Equivalent
United States	100,000	25,000	500	250
Other Free World				
Australia	20,000	5,000	4,000	2,000
Canada	100,000	25,000	500	250
Ceylon	5,000	1,250	300	150
India	60,000	15,000	100	50
Norway	120,000	30,000		
Sierra Leone			3,000	1,500
United Arab Republic	40,000	10,000		
Other	25,000	6,250		
Subtotal	370,000	92,500	7,900	3,950
USSR	100,000	25,000	300	150

Source: Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970 Edition.

CHAPTER FOUR--RESOURCES MANAGEMENT

III--ENVIRONMENTAL ASPECTS OF RESOURCE DEVELOPMENT

III ENVIRONMENTAL ASPECTS OF RESOURCE DEVELOPMENT

A. Statement of the Problem

> ...Man assigns utility to various elements of his environment and thus confers upon them the role of resources. Resources then are neither wholly of the physical world nor wholly of the world of man but are the result of the interaction between the two.[1]

Development of resources to satisfy social needs implies an intimate interaction between man and his environment. Furthermore, the practice of development requires man to carry out operations that are different in character, scale, and rate from the natural processes that controlled the genesis of the resources. These operations inherently represent perturbations to the environment, and it is becoming increasingly important to determine the extent and degree of environmental impacts so that their adverse effects may be mitigated by positive action. This analysis addresses the environmental problems associated with production of mineral resources from which materials important to the DoD may be derived.

The task of defining environmental aspects of resource development is quite difficult. Past activities were frequently developed to emphasize efficient and economical resource recovery, with little consideration given to attendant environmental effects. In fact, the environment adjacent to resource developments usually is considered as a sink for disposal of wastes associated with product recovery. Wastes include solid wastes, emissions into the air, and discharges into waters; frequently, the volume of wastes is many times that of the desired resource product. Also, since wastes usually represent some physical or chemical

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change to original material, their potential for contributing to adverse environmental impacts is considerably enhanced.

Previous practices for disposal of wastes by uncontrolled release into the environment did not necessarily require data on their magnitude or character because they were external to market calculations, and precise information on waste volumes associated with production of common materials is often lacking or at best incomplete. However, this information is essential if resource development practices are to be systematically evaluated to achieve lessened environmental impact. In particular, the amounts of waste of all types (and the media that receive them) need to be identified and categorized for each sequence of production for the common materials used by the DoD. Also, the extent and nature of environmental effects of these wastes need to be described and assessed. Finally, the amounts of other resources (principally water used in association with material processing) required for resource development need to be compiled.

This essential information is necessary to place in perspective the balances of materials used in terms of their resulting environmental impacts. Without this information, no real progress can be made in understanding the interrelated stages of resource development so as to permit the coordinated planning for preserving environmental quality while maintaining supplies of needed resources. The problem, in short, is that many of the unit data required for such an analysis remain to be developed and applied.

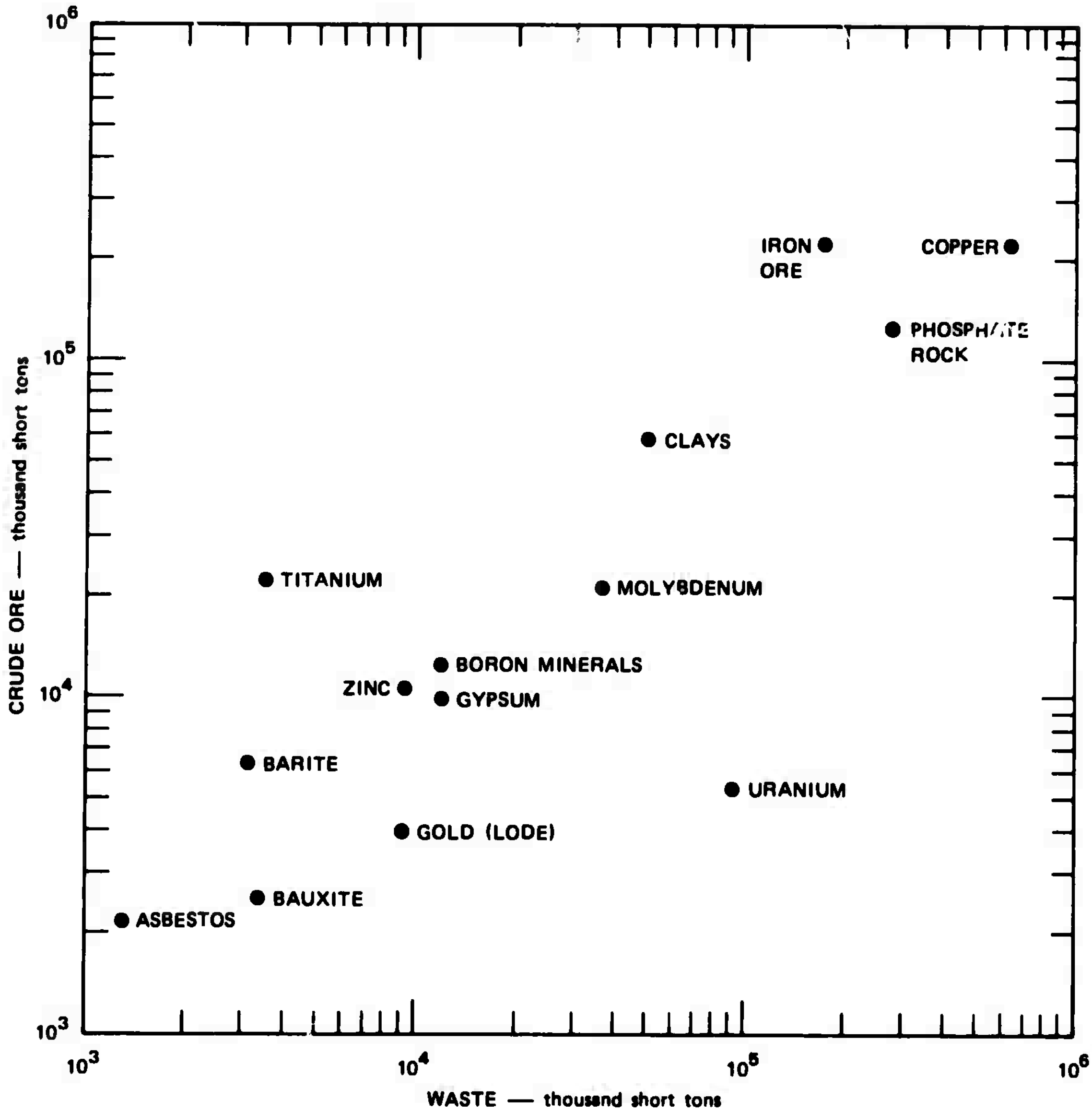
B. State of the Art

The state of the art in assessment of the environmental aspects of resource development is described according to: (1) materials handled (an indicator of solid wastes), (2) emissions (an indicator of air quality), and (3) discharges (an indicator of water quality). Energy associated with materials production and applications is analyzed in a companion report.[2] To the extent possible with the limitations of present data, each major material of concern to the DoD will be examined on a unit basis. However, the short time available for analysis did not permit an exhaustive survey, and the present data are not sufficiently complete at this stage to permit examination of interactions between environmental media in this report.

1. Materials Handled

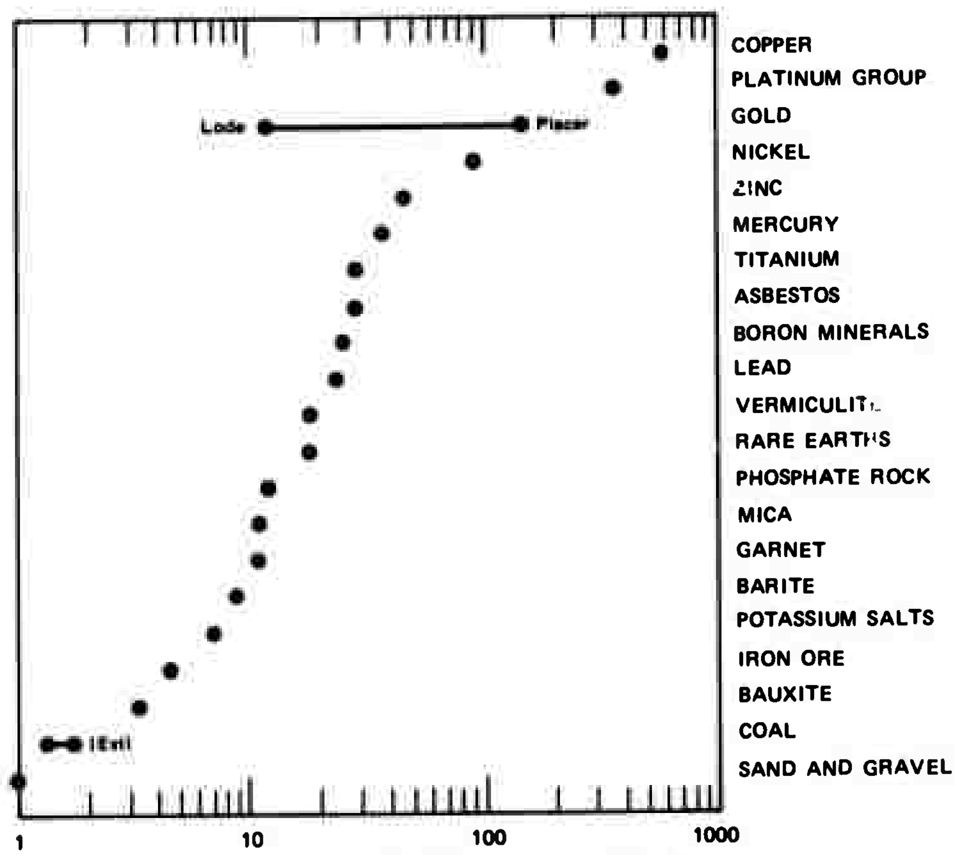
Few minerals occur in a form that permits their use directly; most require some degree of processing to separate the desired commodity or ore from associated waste material. Nevertheless, both ore and waste must be handled as a first step in processing. The amount of materials handled will vary according to commodity, type of deposit, and grade of ore. Figure III-1, compiled from data published by the Bureau of Mines,[3] illustrates the relationship of crude ore to waste handled at U.S. mines in 1969 for common commodities. The figure shows that the amount of crude ore and waste for iron, copper, and phosphate rock are greatest, while asbestos, bauxite, and other materials are less. Clearly, the characteristics of individual materials and phenomena related to their occurrence (especially grade) control the ore-waste relationships for each commodity. However, the data suggest a general trend in which amounts of ore and waste appear to be directly proportional; the more crude ore handled, the more waste (and conversely). This is in part related to ore extraction and processing.

Many ores require further treatment and processing to extract the sought commodity. Figure III-2, also derived from data published by the Bureau of Mines (Reference 3, p. 77), shows the ratio of units of materials handled relative to units of marketable products. Products in this case refer to commodities extracted from the ore. The figure



SOURCE: U.S. Bureau of Mines, *Minerals Yearbook*. Compiled by Stanford Research Institute.

FIGURE III-1 MATERIAL HANDLED AT U.S. MINES (1969)



SOURCE: U. S. Bureau of Mines, ***Minerals Yearbook***, Compiled by Stanford Research Institute.

FIGURE III-2 MATERIALS HANDLED RELATIVE TO MARKETABLE PRODUCT IN 1969 shows that copper has the highest ratio, nearby 600 to 1; in other words, roughly 600 tons of material (ore plus waste) must be handled to produce a ton of copper. The reason is that progress in extractive metallurgy has made possible treatment of very low grade copper ores on a very large scale. Still, significant volumes of wastes are a result of this operation. Other common commodities have lower ratios; iron ore is about 4 to 1, a reflection of its higher grade which makes usable more of the large amounts handled. Sand-gravel has the lowest ratio, 1 to 1, because all the material handled is used. If materials' properties for particular applications are roughly comparable and if it is desired to minimize solid wastes in materials production, then it would seem worthwhile to consider materials occurring toward the right of Figure III-2. Clearly, this approach is incomplete in that minimizing solid wastes may lead to increased impacts on air or water quality; these aspects are described in the following paragraphs as preparation for a discussion of an approach to integrated environmental impact analysis.

The waste problem in resource development is clearly of considerable importance in view of the large amounts of materials used in any given year. The cumulative effects of these wastes can be quite significant in areas of resource development, representing substantial environmental impacts. The Department of the Interior found that more than 3 million acres had been disturbed by surface mining as of 1 January 1965 (Table III-1).[4] The amount has doubtless increased since that time. For example, SRI found that as of October 1971, roughly 250,000 acres had been disturbed by surface coal mining in West Virginia alone.[5] The scope of the disturbance and waste production problem associated with resource development is great. Also, erosion of mined lands and waste areas leads to water quality, flood control, and navigation problems of concern to the DoD in connection with its civil responsibilities.

Table III-1

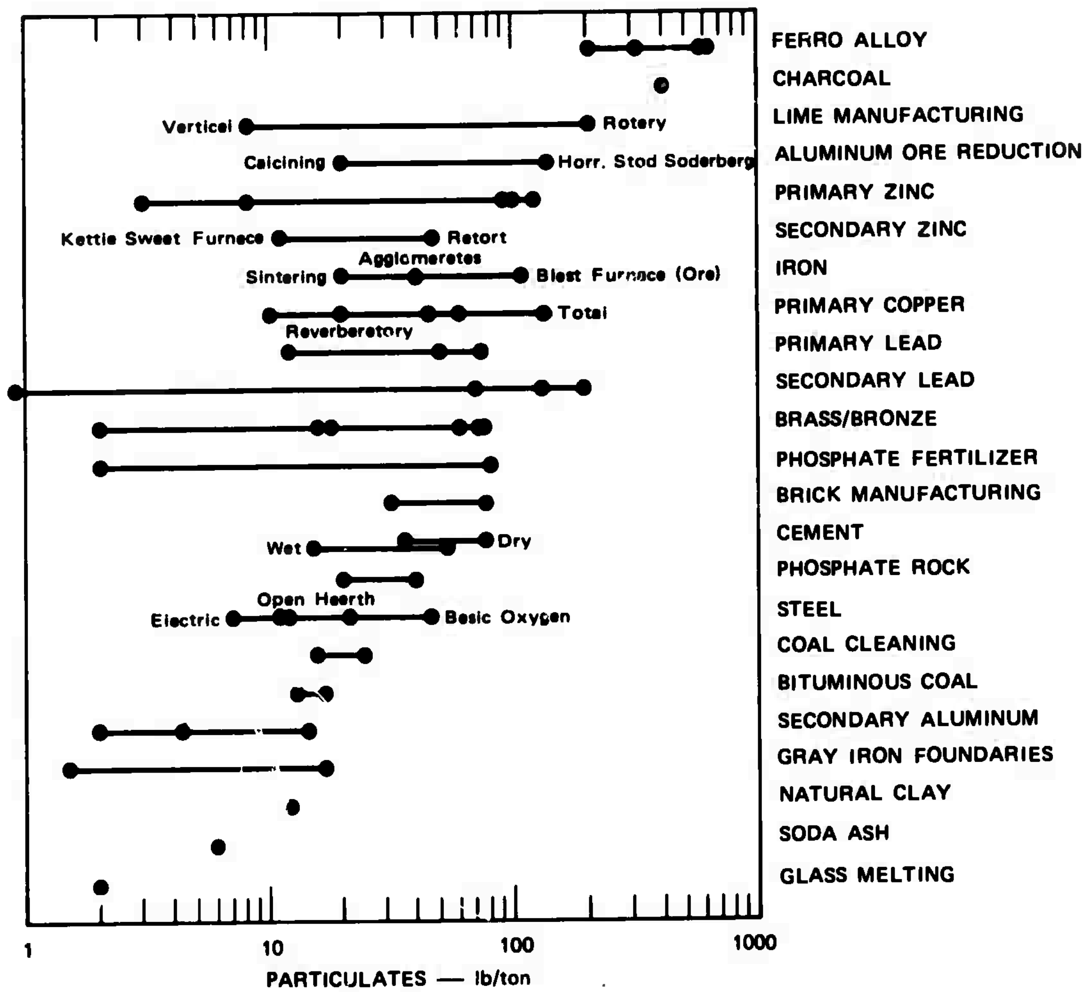
LAND DISTURBED BY STRIP AND SURFACE MINING IN THE UNITED STATES AS OF 1 JANUARY 1965 (Acres)

Commodity	Land Disturbed
Clay	108,513
Coal	1,301,430
Stone	241,430
Sand and gravel	823,300
Gold	203,167
Phosphate rock	183,110
Iron ore	164,255
All other	162,620
Total	3,187,825

Source: U.S. Department of the Interior, "Surface Mining and the Environment," 1967.

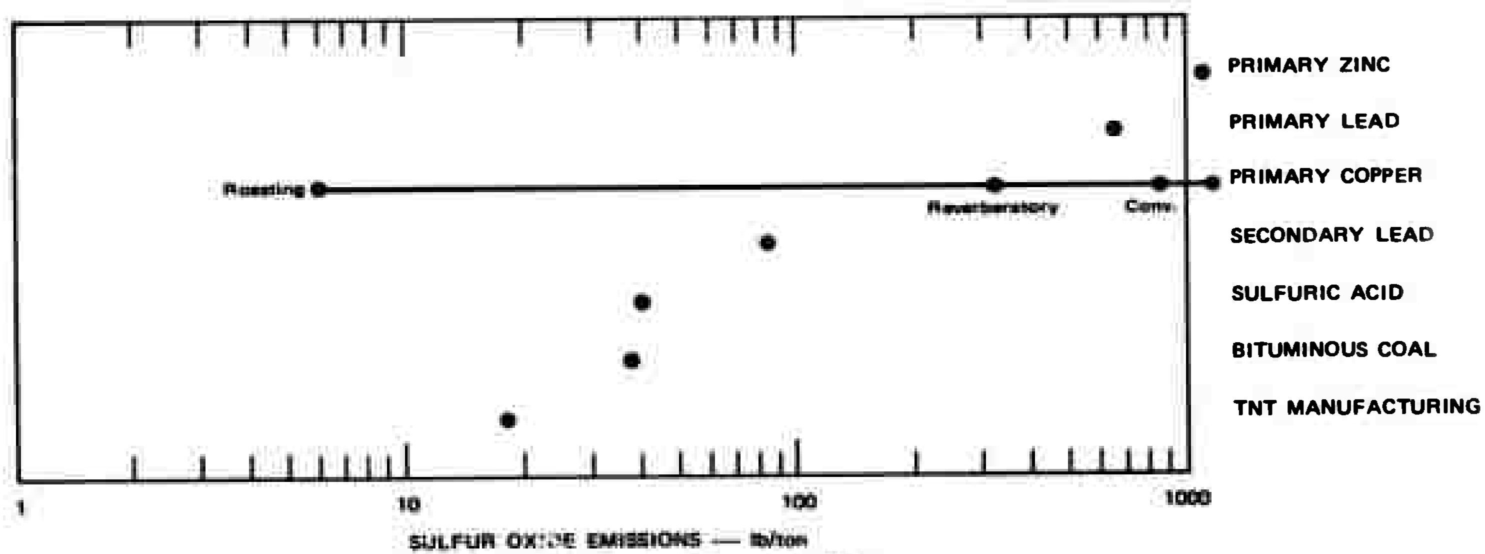
2. Air Quality

Processing of ores can release emissions to the air that influence its quality level. These emissions have been compiled by the Environmental Protection Agency,[6] and are expressed on a unit basis, e.g., pounds of particulates per ton of product associated with a given process. Figures III-3, 4, and 5 present these data for particulates, sulfur oxide emissions, and nitrogen oxide emissions. As in Figure III-2, the data are presented in descending order with the highest values at the left. Other things being equal, materials or processes that lead to lesser emissions would seem to be preferred over those that lead to greater amounts (again, it is necessary to consider related environmental effects in other media).



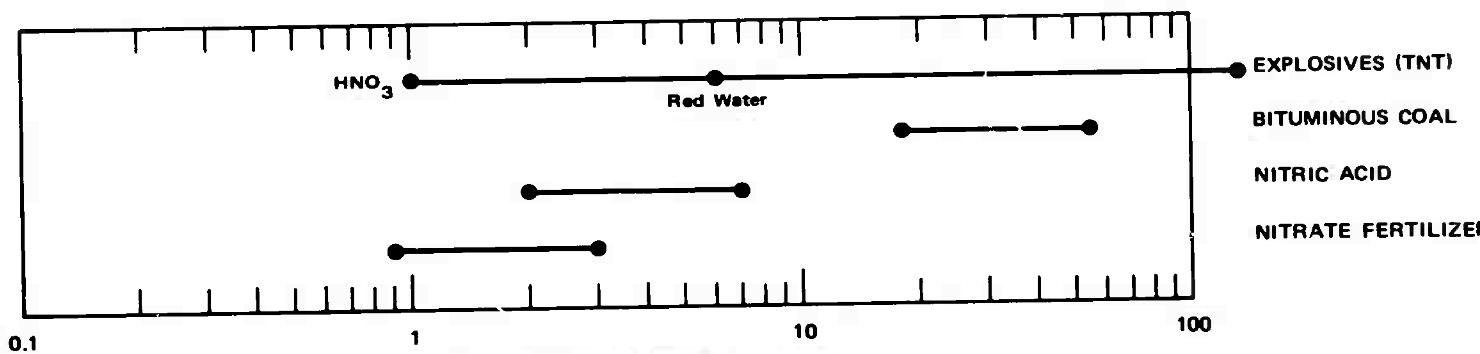
SOURCE: Environmental Protection Agency. Compiled by Stanford Research Institute.

FIGURE III-3 PRELIMINARY COMPILATION OF PARTICULATE EMISSIONS ASSOCIATED WITH MATERIALS PROCESSING



SOURCE: Environmental Protection Agency, Compiled by Stanford Research Institute.

FIGURE III-4 PRELIMINARY COMPILATION OF SULFUR OXIDE EMISSIONS ASSOCIATED WITH MATERIALS PROCESSING



SOURCE: Environmental Protection Agency, Compiled by Stanford Research Institute

FIGURE III-5 PRELIMINARY COMPILATION OF NITROGEN CXIDES EMISSIONS ASSOCIATED WITH MATERIALS PROCESSING

The importance of air quality factors may be demonstrated by two examples.

- A 1000 megawatt coal-fired generating unit consumes about 400 tons of coal per hour. If this fuel has 3 percent sulfur, this represents the production, each hour, of 12 tons of sulfur, or 24 tons of SO_2, or 36 tons of H_2SO_4.[7] On a national basis, roughly 9 million tons of sulfur is released by power plants each year.
- Copper smelters produce about 3600 tons of acid per day;[8] on an annual basis, this amounts to more than one million tons.

The presentation of air quality impacts in unit terms enables assessment of the relationships to process characteristics and quantities and permits evaluation of the environmental aspects of materials production on airsheds in the vicinity of developments of plants.

3. Water Quality

Resource development also contributes to effects on water quality; the degree of effect varies with industry and process. Water is used in resource development for cooling and as an additional process constituent. However, data on water quality effects are in less usable form than those for materials or emissions. The principal source of data encountered in this brief examination is a survey conducted by the Conference Board.[9] Although the survey did not provide complete coverage, the total wastewater volume and characteristics of survey participants were presented, together with the number of plants, permitting calculation of the wastewater discharge at "typical" plants. Although somewhat artificial because of the form of available data, this approach does provide some guidance to evaluation of the water quality factors associated with resource development. A set of figures was prepared from these data to represent the following daily discharges at a typical plant:

Figure III-6	Untreated wastewater discharge
Figure III-7	Treated wastewater discharge
Figure III-8	Biological oxygen demand (BOD)
Figure III-9	Chemical oxygen demand (COD)
Figure III-10	Suspended solids

As in earlier figures, the data are presented in descending order from left to right. Because each process or industry will have different amounts of discharges in each category, the order of presentation will vary for each figure. Other things being equal, it would appear that the processes or industries occurring to the right would have lesser environmental impact and might for that reason be favored over others with greater discharges.

Figures III-6 and 7 present data in gallons of wastewater discharged, which sets them apart from the other charts in this section that give data in units of weight. This reflects the original data; to convert to pounds, multiply data in gallons by 8.35; to convert to tons, multiply by 4.175×10^{-3}.

The limitation in these data on water quality is that they do not include information on the capacity of individual plants, and therefore it is not possible to directly relate a unit of discharge to a unit of production for the industries surveyed. It would be possible to estimate unit discharge/production relationships by making assumptions regarding the capacity of typical plants. However, since there is no guarantee that the assumed capacity is represented by the plants included in the survey, the uncertainty in this approach appears to be large. Information that may be of assistance in this task was recently summarized,[10] although great care is needed to avoid misleading results. The relationship of water discharge data to unit production of key commodities needs to be determined for major processes if environmental assessments are to be performed.

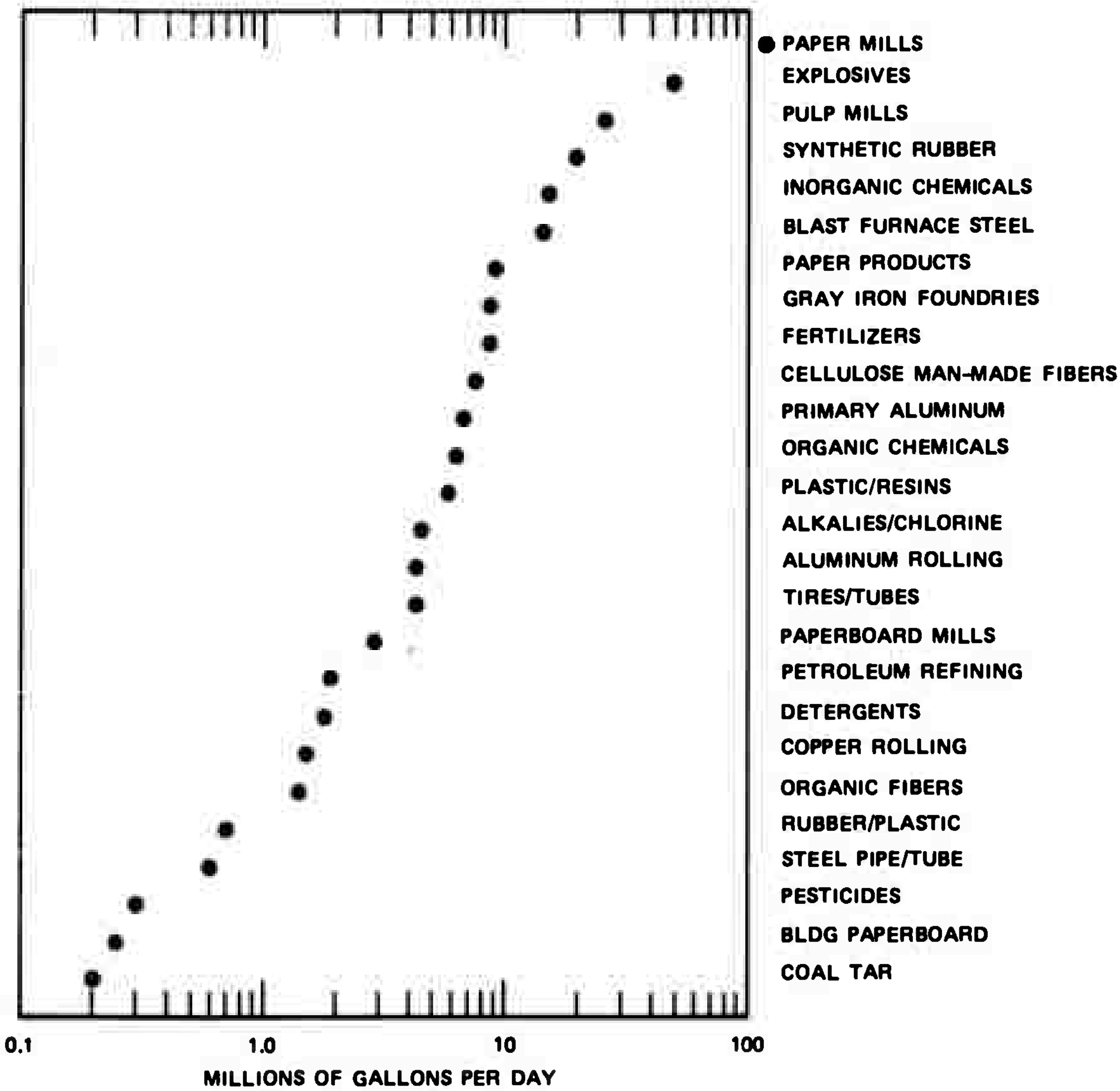
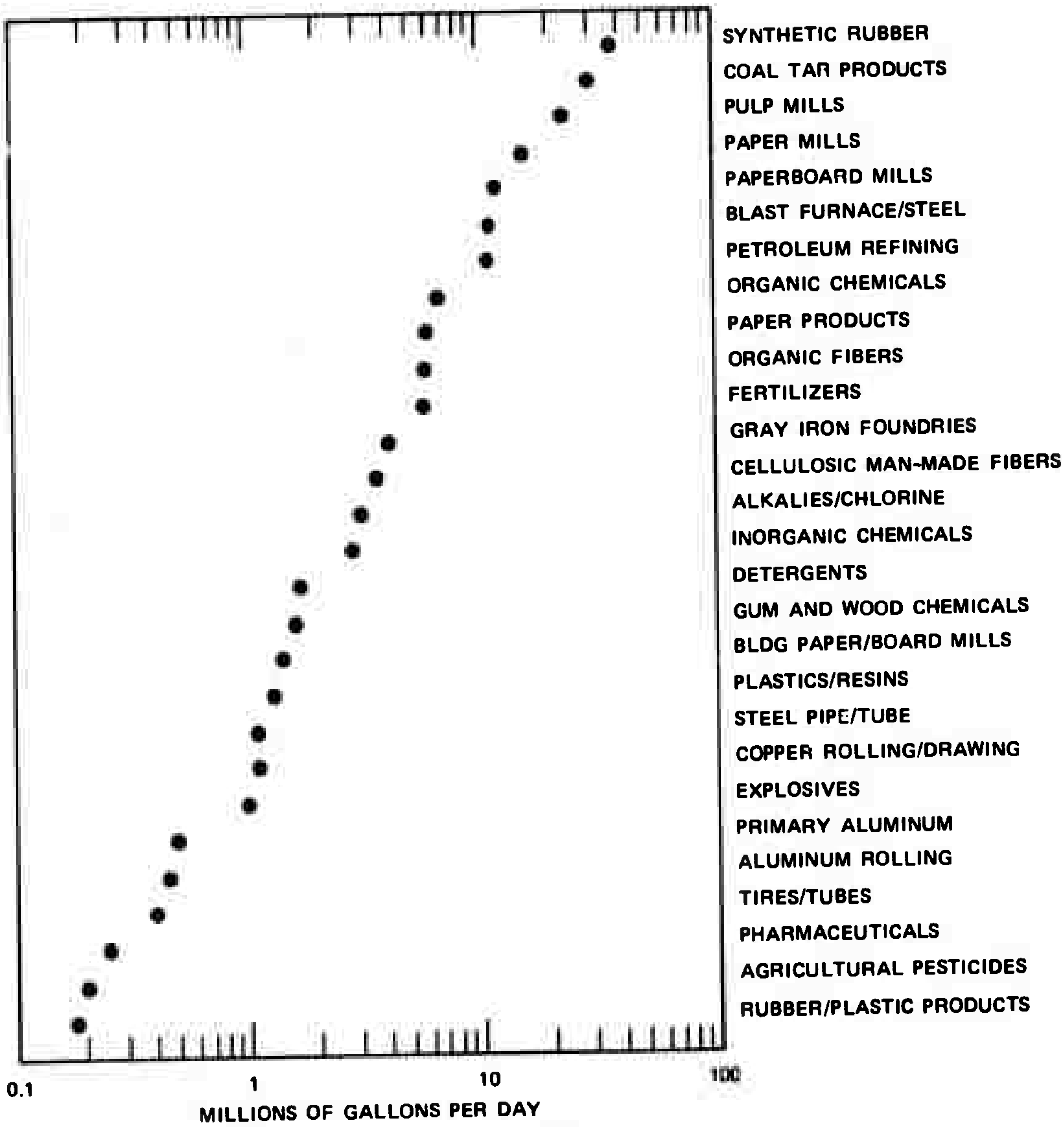
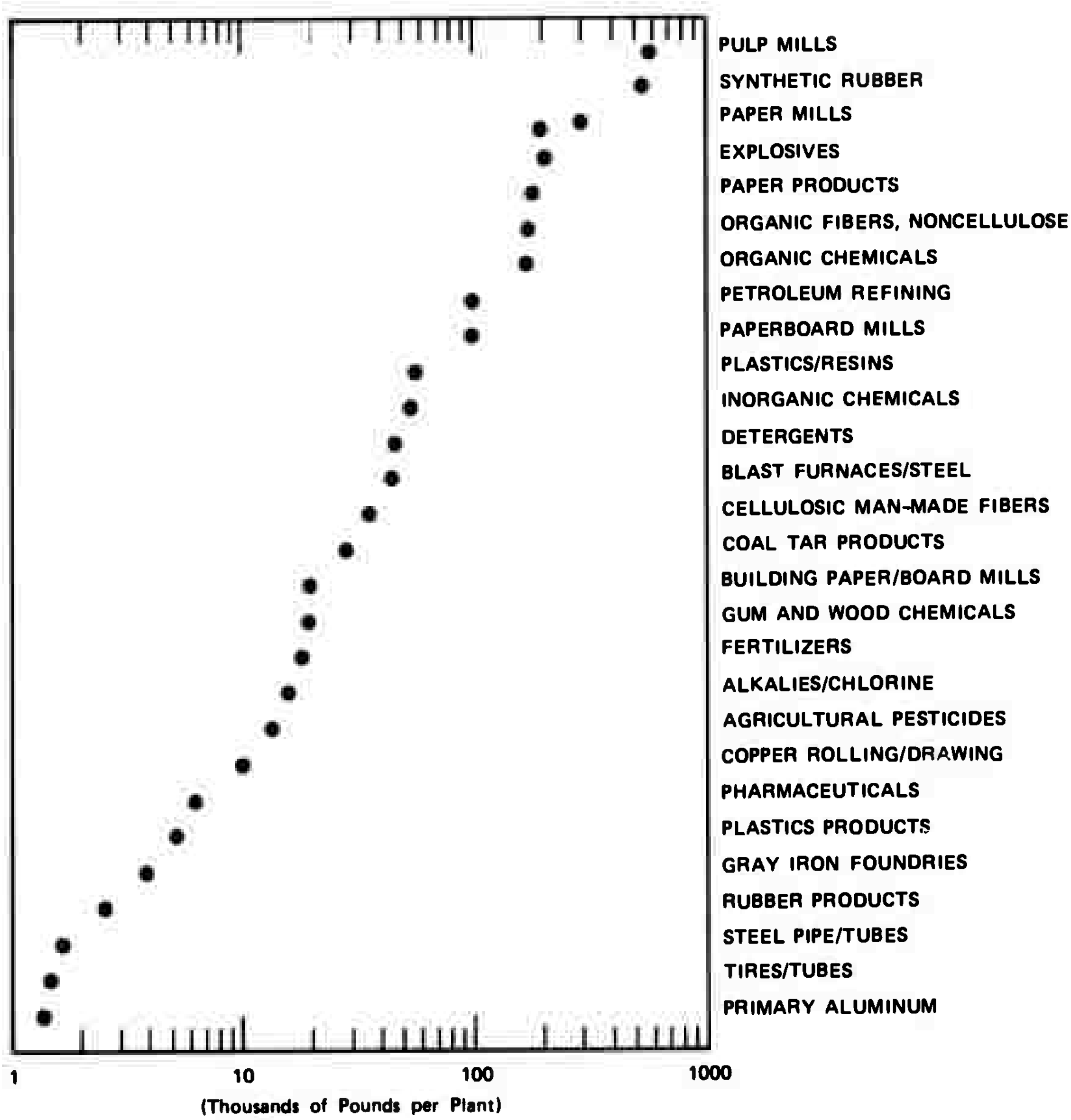


FIGURE III-6 TYPICAL UNTREATED WASTEWATER DISCHARGE BY INDIVIDUAL PLANTS



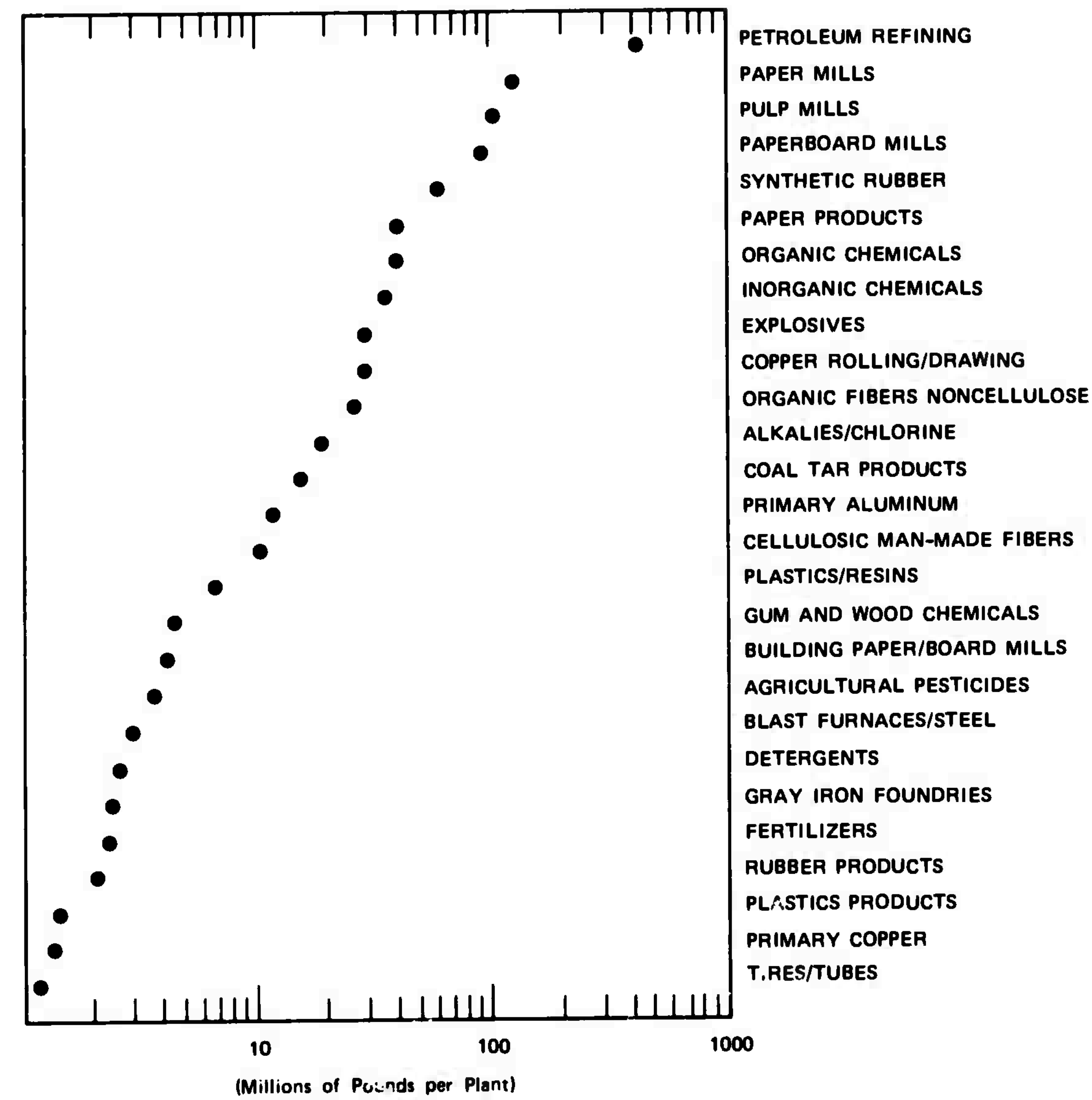
SOURCE: Industry Expenditures for Water Pollution Abatement, The Conference Board, Inc., New York, 1972, p. 98.

FIGURE III-7 TYPICAL TREATED WASTEWATER DISCHARGE BY INDIVIDUAL PLANTS



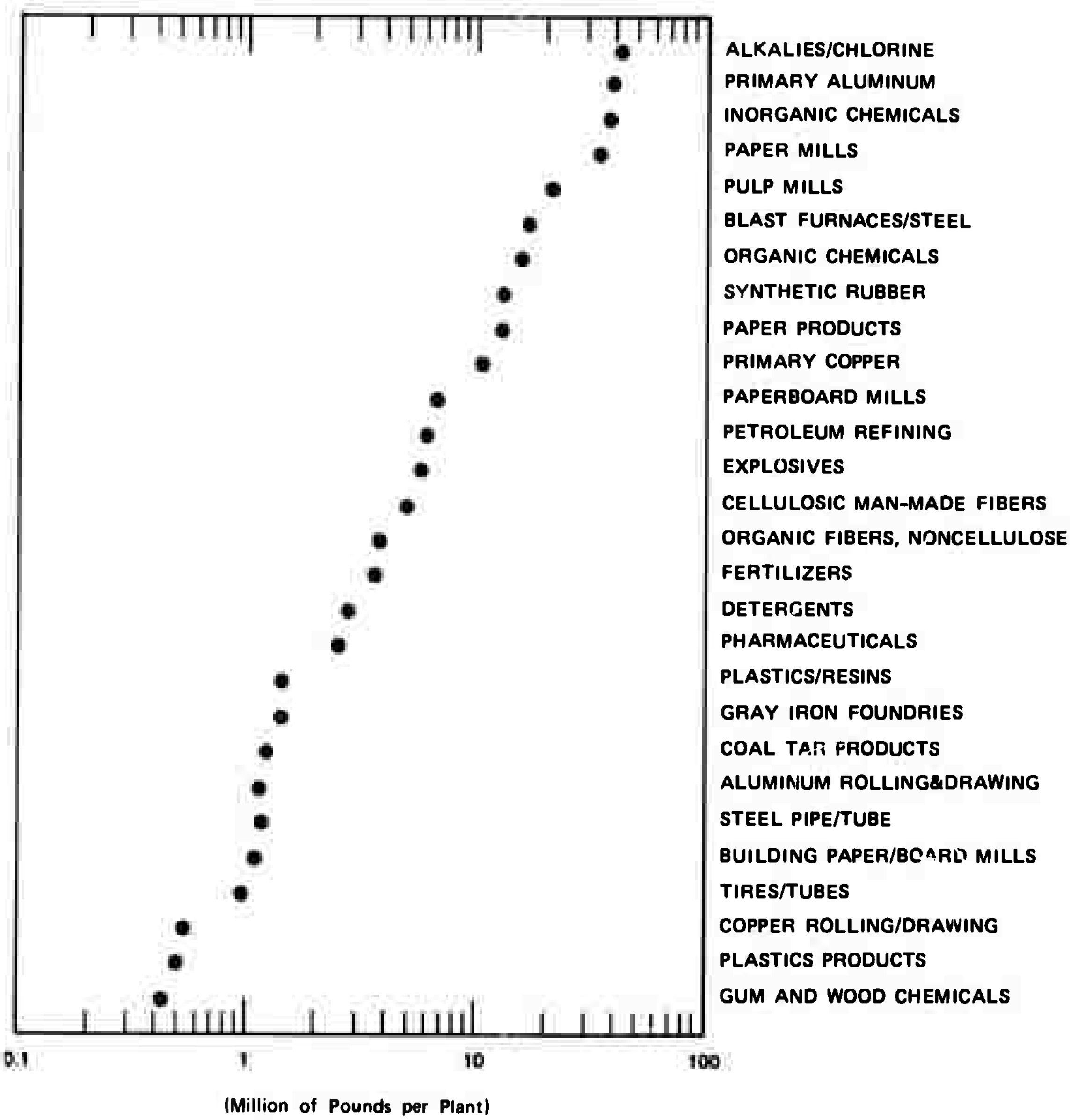
SOURCE: Industry Expenditures fo· Water Pollution Abatement, The Conference Board, Inc., New York, 1972, p. 99.

FIGURE III-8 TYPICAL BOD CONTENT IN UNTREATED WASTEWATER DISCHARGE



SOURCE: Industry Expenditures for Water Pollution Abatement, The Conference Board, Inc., New York, 1972, p. 100.

FIGURE III-9 TYPICAL COD CONTENT IN UNTREATED WASTEWATER DISCHARGE



SOURCE: Industrial Experditures for Water Pollution Abatement, The Conference Board, Inc., New York, 1972, p. 101.

FIGURE III-10 TYPICAL SUSPENDED SOLIDS CONTENT IN UNTREATED WASTEWATER DISCHARGE

The capacities of typical plants can be estimated from available data, observing the above cautions. The steel industry is used to illustrate the estimating process. It has been noted that "all the iron produced in an integrated steel mill originates at the blast furnaces...."[11] According to the U.S. Bureau of Mines,[3] 95 million tons of pig iron were produced in 1969, and there were 228 blast furnaces in the United States during that year. On the average, annual production would be about 417,000 tons per furnace. Assuming that each furnace operates for 330 days per year, roughly 1300 tons is produced daily by each furnace.* If a typical steel plant has 5 furnaces (Reference 11, Figure 5), then such a plant produces about 6500 tons of pig iron per day. Conference Board data[9] indicate that a typical blast furnace/steel plant discharges roughly 12 million gallons per day. Therefore, in terms of unit production, the daily discharge from a typical steel plant would seem to be about 1850 gallons per ton. However, evidence suggests that this figure is too low. The Conference Board found that the steel industry was "least cooperative" with its survey, and that the responses received from steel companies represented only a small fraction of the total, with many of the largest not responding.† Accordingly, the actual total wastewater discharge for a typical steel plant used in the above calculation is probably greater than the apparent result. "In general, where water is plentiful and pumping costs are low, the industry tends to use water freely."[12] "It has been estimated that as little as 2 percent of the circulated (water) supply (in steel plants) is actually consumed; the remainder is

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* Taken from other metal industries listed in "The Economic Impact of Pollution Control."[10] This calculation is in excellent agreement with <u>Mineral Facts and Problems</u> - 1965 Edition, which states that "the average blast furnace in the U.S. ... will produce about 1200 tons of pig iron per day." p. 462.

† Telephone interview with L. Lund, September 28, 1972.

returned to the natural drainage basin in which it originated (or re-used)." (Reference 13, p. 262.) "In older mills of the East and Middle West, most ... water is used on a once-through basis; in the West where water is less plentiful, a high percentage of the water is collected and reused."[11]

Water required for taking raw iron ore to steel products is generally in the range of 20,000 to 40,000 gallons per ton.[11] If most of this is used on a once-through basis in older mills, then the daily discharge of a typical steel plant could be about an order of magnitude greater than that indicated by data obtained in the Conference Board survey. The actual figure will vary with process and location, indicating the need for further research to determine these factors with greater precision. Similar work is needed for other common commodities such as aluminum and copper to provide for assessment of the overall environmental impact associated with their development.

C. Synthesis of Environmental Aspects of Resource Development

As the foregoing data illustrate, attention has been most frequently focused on the impact from resource developments on individual media constituting the environment. For example, considerable amounts of data exist on certain aspects of air and water quality. However, little attention has been given until recently to an integrated analysis of the overall environmental impact of any given process or industry. Part of the reason for this has been a lack of process-related data that express environmental impacts on a unit basis to serve as a common reference base to guide the analysis. The previous discussion suggests that this condition may be alleviated through systematic research. Clearly, this form of analysis is essential if progress is to be made in recognizing opportunities for process improvement to minimize adverse environmental effects while controlling costs to manageable levels. Two recent illustrations of this form of analysis cover a gypsum plant[13] and the U.S.

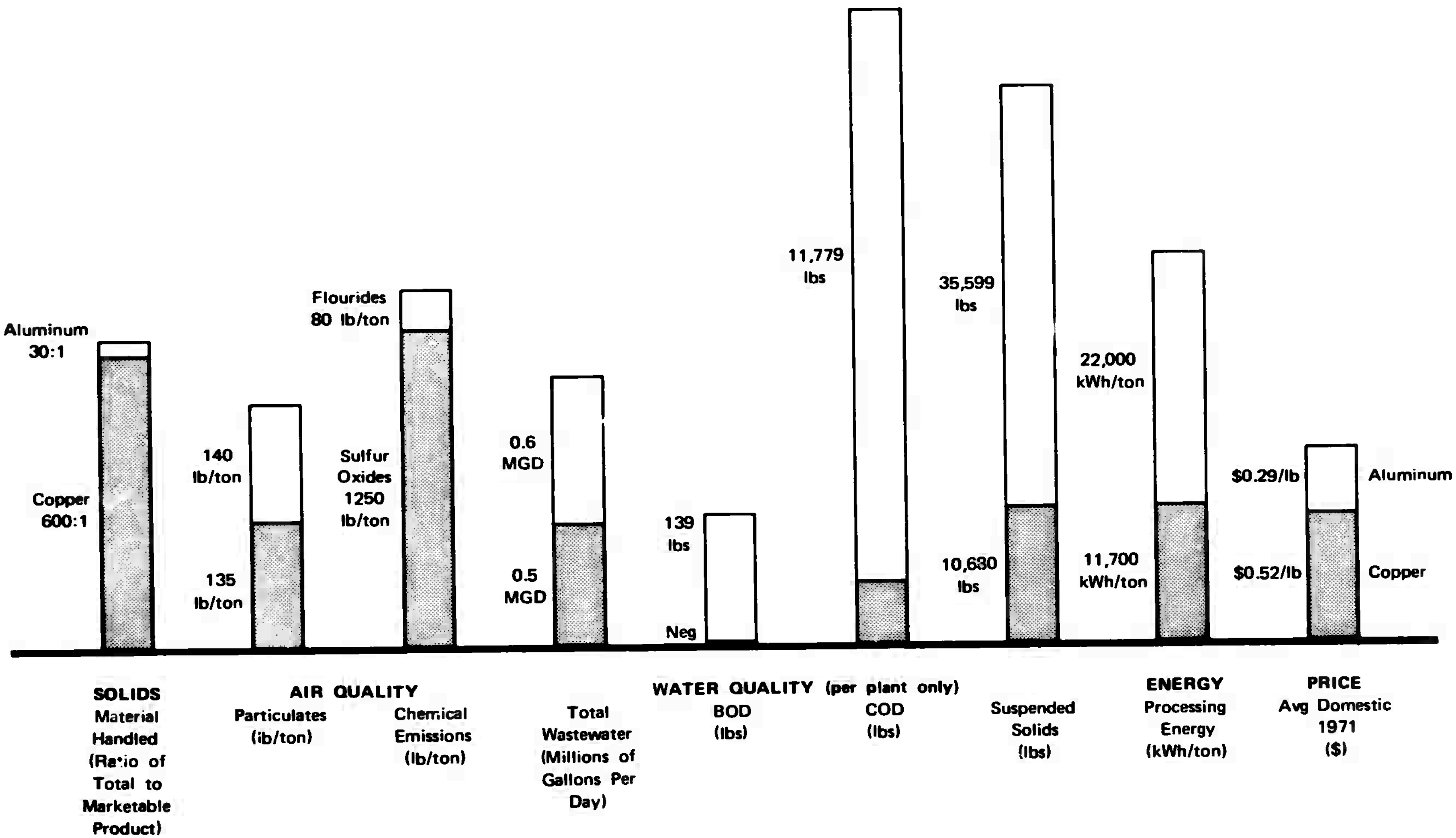
cadmium industry.[14] Each study identifies the sources and amounts of emissions from various stages of the production sequence, facilitating the design and implementation of abatement and control programs from a technical standpoint. The same approach should be extended to examination of the environmental aspects of other key materials of importance to the DoD. With a complete data base, the overall environmental impact of these materials can be assessed, facilitating the establishment of advanced research programs to deal with critical problem areas. Additionally, the technical data for each stage of the production sequences need to be balanced by compilation of the major institutional factors that pertain to production so as to place operations in perspective and recognize possible constraints to implementation of technical advances. This will represent a major research undertaking. The scope of study will be broad because of the variety of processes for materials production, the range of environmental impacts related to process type and volume, and the diversity of characteristics of the ambient environment itself.

Two initial attempts to illustrate the approach to overall environment assessment are described below, one in which the apparent impact of two materials is compared, and the other in which the impact of a material used in a common application is analyzed. In each case, the analysis is preliminary, intended only to demonstrate the concept that quantitative analysis of environmental impacts of resource development is feasible.

1. Comparison of Environmental Factors for Copper and Aluminum

Copper and aluminum are important commodities in that significant quantities are produced and consumed annually in the United States. Increasingly in recent years, aluminum has been substituted for copper, especially in electrical applications, to take advantage of the weight saving and the lower unit cost. However, it is instructive to include environmental aspects in the analysis leading to a choice between these two metals to provide for a more complete accounting of costs associated with their use. Figure III-11 summarizes data for copper and aluminum from the preceding sections. The figure shows that copper requires the handling of 20 times more material than aluminum, the amount of particulates released is virtually identical for each, and the amount of SO_2 emitted in copper processing is about 15 times the fluorides released in aluminum processing (although the greater toxicity of fluorides offsets this). The water quality effects are difficult to quantify because of lack of data on individual plant capacity as discussed earlier. Qualitatively, the data suggest that aluminum processing has a greater impact on water quality than does copper, but more work is required to verify or refute this preliminary conclusion. The figure shows, finally, that aluminum requires roughly twice as much processing energy as copper, and that the price of aluminum is roughly half that for copper (probably because of the availability of cheap power).

In summary, the data presented in Figure III-11 (admittedly preliminary and incomplete) suggest that in environmental terms the substitution of aluminum for copper results in energy-intensive operations that appear to have greater water quality effects (aluminum) replacing operations in which large quantities of solid wastes are handled and in which air quality effects are significant (copper). To complete the analysis and provide a quantitative basis for evaluation of the total costs associated with development of these resources, it will be necessary to assign dollar values for controlling these unit environmental impacts. The present state of data on environmental economics appears to be approaching the point where this is possible, so long as a unifying concept such as treating all impacts on a common basis is used to standardize the procedure. This work is necessary to avoid reliance on arbitrary "indices" of environmental quality that are unrelated to



SOURCE: Stanford Research Institute.

FIGURE III-11 COMPARISON OF ENVIRONMENTAL FACTORS FOR COPPER AND ALUMINUM the causes of problems and thereby offer little in the way of guidance for remedial or preventive action in resource development and in choices regarding materials applications for DoD purposes.

2. Analysis of Environmental Aspects of Steel in a Typical Automobile

The above analysis used unit data to obtain an overview of the problems in development of two resources without particular regard to ultimate use. The data may also be used to arrive at a preliminary evaluation of the environmental aspects of specific uses. The materials constituting a typical U.S. automobile were estimated[15] to be as follows (in pounds):

Iron and steel	2,775
Copper	50
Lead	25
Zinc	50
Rubber and plastic	250
Glass	100
Aluminum	100
Miscellaneous	150
Total	3,500

The data show that iron and steel constitute nearly 80 percent of a typical automobile. Therefore, examination of the environmental effects of iron and steel development should provide an initial assessment of the environmental impact of constructing an automobile. When combined with the existing data that describe the environmental effects of automobile operation, these data may offer a more complete definition of the total impact and aid in identifying practical solutions for adverse effects. As well as being a tangible product with which most people are familiar, the automobile accounts for significant resource use, representing about one-fifth of total annual U.S. steel consumption.[15] Also, it was noted that:

> ... 1971 U.S. production of 8.6 million automobiles plus 2.1 million new commercial vehicles generated mineral demands <u>substantially greater</u> than 10.7 million times the above quantities. [emphasis added][15]

The reason for this is that other resources required for production of these materials have not been taken into account; for example, the coal and limestone associated with iron and steel production are not represented. A thorough materials balance analysis is required to account for these essential resources as well. However, an indication of the type of analysis is provided by examining steel in a typical car. Table III-2 presents data on materials, air quality, and water quality impacts associated with steel production for a car. The table suggests that roughly ten times as much material is handled as the steel that is in the car.* The water and air quality impacts also appear to be substantial; again, this is incomplete in that higher-order factors are not included in this first attempt. In spite of these limitations, this brief analysis does indicate that the environmental aspects of resource development are quantifiable according to classes of common items of equipment, and it seems possible to extend the analysis to include common classes of facilities.

The basic approach to identification of the details of environmental aspects of resource use in typical applications is important to achievement of environmental quality controls, but has its greatest potential in facilitating recognition of means to conserve and reuse critical resources. Available information about the supply of natural resources strongly indicates impending shortages in essential materials before the end of the century.[16] Similar warnings about shortfalls in

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* Actually, the factor is greater than this because of the associated materials required to process iron ore and produce steel.

Table III-2

PRELIMINARY ENVIRONMENTAL IMPACT COMPILATION:
STEEL IN TYPICAL U.S. AUTOMOBILE

Materials impact (pounds)	
Steel*	2,775
Waste* (@ equivalence to steel)	2,775
Total ore	5,550
Materials handled† (@ 4.5 x ore)	24,975
Water impact (gallons)	
Steel (2775 lb = 1.37 tons)	
Total water‡ (@ 30,000 gal/ton)	41,100
Not reused‡ (@ 58% of total)	24,838
Air impact (pounds)	
Steel (@ 1.37 tons)	
Particulates§ (@ 500 lb/ton)	685

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* Reference 16.

† Reference 3.

‡ Reference 11.

§ Reference 6.

energy supply were made ten years ago but were largely ignored. Although the material resource problem is not yet as serious as the short term energy situation appears to be, action is needed now to permit positive programs to expand the available options for material supplies to meet expected demands in, say, 1985. Knowledge of the materials balances for basic processes will be essential if the nation is to fulfill its material needs without undue dependence on imports that could influence its security posture.[17]

3. Factors for Analysis of Total Environmental Impact

Pollution abatement and control regulations are being implemented by all levels of government in an effort to alleviate the adverse effects of pollution on society and the environment. These regulations stem from major federal actions aimed at improving environmental quality as indicated by tolerable standards for conditions in media such as air, water, and land. Environmental quality regulations represent an attempt on the part of government to internalize costs associated with the production of goods or services by industry but that are ordinarily outside their market calculations and are thereby borne at present by society at large.

It must be kept in mind, however, that just as the environment may be affected by development in a complex manner that is difficult to predict in advance, so too can the consequences of certain pollution control regulations lead to unforeseen, complex, and far-reaching economic impacts. In short, the economic aspects of pollution control require as careful analysis as does the assessment of effects on the physical environment to avoid creation of equally undesirable conditions.

Analyses of economic impacts of environmental pollution control may be potentially misleading unless they take into account both the primary factors relative to major industries and the higher-order effects relative to the transactions carried on by these industries with other sectors of the economy. The difficulty of conducting thorough analysis of this type is great, and many previous studies have either been too broad to be relevant to particular cases or too specific to permit derivation of generalizations that can be applied to other cases. Clearly, sufficient detail is required to achieve representation of basic transactions and recognition of principal factors affected by costs for pollution control. This is an ambitious goal that will require a major research undertaking.

It is also essential to recognize that the environmental aspects of pollution control and the economic impacts stemming from these controls exist in an institutional framework that can shape the nature of regulations and thereby determine costs associated with their implementation. In short, there are also complex patterns of institutional transactions among government agencies (at all levels) and industry that exert important influences on the result in terms of environmental quality and costs related to its pursuit. This factor is often overlooked as attention focuses on achievement of control of particular forms of pollution or related costs; yet, institutional factors can be of overriding importance because they shape the scope and direction of the other factors (and if changed by legislative or executive action, can lead to entirely different sets of environmental and economic conditions).

Consideration of the impact of governmental procedures and regulations on energy and resource development industries thus must include environmental, economic, and institutional factors or otherwise be incomplete. The problem of analysis appears to be significant for any one state because of the complex interactions of these factors. The problem is compounded on a national scale when it is recognized that the several states (and regional associations of states) use their own distinctive approaches to government and to regulation of industry and often represent distinctly different environmental conditions that may be at variance with adoption of common requirements.

Notwithstanding the complexity of the problem, it does appear to be amenable to a comprehensive and interdisciplinary analysis that addresses the interrelationships among pertinent factors. The analysis will require involvement of experts in each of the three principal topics, especially those who can recognize the contribution they can make to completing the understanding of colleagues in related fields (and conversely) that is required to achieve progress in addressing this complex set of problems.

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CHAPTER FOUR--RESOURCES MANAGEMENT
IV--ENVIRONMENTAL ASPECTS OF ENERGY DEVELOPMENT AND USE BY THE DEPARTMENT OF DEFENSE

IV ENVIRONMENTAL ASPECTS OF ENERGY DEVELOPMENT AND USE BY THE DEPARTMENT OF DEFENSE*

A. Statement of the Problem

All U.S. institutions that produce, distribute, or use significant quantities of energy are coming under close public scrutiny. The effect of this public pressure is to achieve some measure of control over the heretofore rapid growth in energy use so as to begin to ameliorate associated environmental effects. Air pollution probably is the most conspicuous impact of energy in most people's environment. An additional factor relates to the land use patterns associated with energy. Objections have been raised not merely to the space occupied by generating stations, fuel refineries, and coal mines but also to the transmission lines that accompany them.

Another class of concerns relates to the public safety aspects of energy production and transport--most notably, nuclear hazards, although pipelines and fuel transportation by rail and tanker are also important in this regard. Also of concern are the effects of ecological changes from energy production and use--principally heating of local waters, air pollutant effects on local flora and fauna, and the potential of climatological change resulting from intense local use of energy. Another growing source of environmental pressure derives from the belief that economic growth is itself responsible for environmental degradation, and thus some limits to energy supply would be an effective means to halt these advance effects.

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* This section is reproduced from SRI's earlier draft report, "Support of Energy Program Planning," submitted to ARPA 1 September 1972.

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The impending fuel supply shortage will exacerbate the environmental concern. It will force utilities and large fuel consumers to use coal instead of gas and oil. Emissions of sulfur dioxide and particulates will probably increase, resulting in further deterioration of air quality in affected urban areas. There will be a drive to avoid the emissions from dirty fuel by using stack gas scrubbing equipment and by installing coal gasification plants; but it seems probable that some actual further deterioration of urban air quality will be experienced, stimulating the development of institutional reforms that will provide more effective incentives for improvement of environmental quality.

The additional coal supply can most cheaply be obtained from strip mines. These mines already are a focus of public concern because of the disruptions to the landscape and impairment of amenities through offsite effects that accompany mining. Unless progress is made in rehabilitation of surface mined lands to permit some further use, it is apparent that public pressure will severely restrict coal supply from this technique. As more nuclear plants are built, the risk associated with them will become more immediate or, at least, more readily appreciated. All these effects of the fuel shortage will be highly visible environmentally, with resulting public concerns being focused on them.

The air pollution and land use impacts from energy development on individuals are immediate, direct, and personal. The impacts themselves are obvious motives for citizens to join in exerting environmentalist pressure; no ulterior motives need be ascribed, although some may exist. On the other hand, the hazard aspects and the local ecology effects associated with energy sources cause concerns that are remote and more difficult to demonstrate. While they are legitimate matters of concern, that concern must finally be about whether established authority will deal competently with them before they rise in scale and impact to the level of many present air pollution and land-use problems.

These concerns are not limited to individuals who oppose the "establishment;" and it cannot always be assumed that environmental pressures are exerted only by chronic social critics. The highly motivated and articulate but smaller groups will lead the less organized, impacted public in specific opposition or reform projects. Therefore, the DoD can expect continued, searching scrutiny and environmentalist intervention on all its activities that have environmental impact--including its use of fuel and electric power. The degree to which such intervention can affect these activities will be a measure of the effectiveness of programs to mitigate environmental impacts of energy development and use by the DoD.

B. State of the Art

The DoD is exposed to these energy-related pressures as target in three major roles that illustrate the state of the art:

- As a fuel user and thereby, polluter
- As a priority consumer of energy in short supply
- As a holder of fuel reserves.

In a fourth role, the DoD can be an environmental problem-solver.

A relatively conspicuous fuel consumer-polluter is DoD aircraft operations. In the vicinity of urban bases where they operate at low altitudes, the noise and visible exhausts from aircraft will affect the air quality conditions more or less as their contribution to the surrounding air is more or less obviously polluted. Attention will be attracted to the nitrogen oxide (NO_x) emissions of these aircraft--especially in urbanized air basins where photochemical smog is a principal ingredient of the urban haze. In general--and until at least 1980, by which time significant numbers of NO_x-controlled automobiles are projected to have entered the population--the aircraft contribution to the total pollution load will be small; and the DoD portion of this will be still smaller.

Automobiles are, and will continue to be, the source of most of this pollutant; electric power plants and industrial combustion rank close behind. But the fact that DoD operations are controllable by order will expose them to increasing pressure for actions to control pollution from these sources. There are obvious approaches that DoD may use to respond to these situations. From the standpoint of technology, it is clear that DoD support of technological developments leading to improved smokeless engines and low NO_x combustors is also indicated.

It will be important to establish the basic facts concerning the question of NO_x emission in the stratosphere. This concern--that depletion of ozone through the very rapid reaction, $NO + O_3 \rightarrow NO_2 + O_2$, would strip away part of the atmosphere's ultraviolet absorption--was a factor in the SST debate. Until it is resolved, it will remain as a member of that class of phenomena--such as nuclear power plant disasters, and certain chemical pesticide uses--around which scenarios can be constructed that, through a converging chain of events, lead to ecological catastrophe. The DoD, as with other government agencies, will be obliged to investigate the elements of such scenarios no matter how improbable they may appear to be. Analyses of alternative actions are required as part of the Environmental Impact Statements--prepared in compliance with the National Environmental Policy Act. Such analyses can be valuable in determining whether significant use can be made of exotic fuels--pentaborane, for example--or in advance of the development of aircraft that will operate significantly higher than the altitudes at which much experience has been gained.

DoD land installations are being required to adhere rigorously to the emission standards for air and water pollution that govern the surrounding community. Particularly in reference to energy matters, the emissions of heating plants, local power generating plants, fuel storage, and transfer equipment will be points of scrutiny. Defense installations should be prepared to make early installations of pollution control equipment as it becomes commercially available. It is to be expected that boiler stack gases and, possibly, stationary diesel exhausts, will be required to be scrubbed of particulates, SO_2 and NO_x. Equipment for the former is widely available, since SO_2 removal is approaching commercial utility, while NO_x removal is still in the laboratory. These requirements could significantly increase operating costs of the plants affected.

Similar pressures will be applied to vessels in port. Here the pressures already felt to prevent oil emissions to the water will intensify as the oil-spill problem is intensified by growth of oil imports. Already much improvement has been noted in the previously used practices of fuel transfer and tank cleaning. Information on other activities of pollution control is presented below.

C. Present Activities Relative to the Status of Environmental Information

The environmental aspects of energy development constitute a complex set of secondary or higher order effects that are caused by (or related to) primary activities for stages of the process by which energy is produced and used. In short, they are what economists term "technical externalities," those that have been outside the market calculation of the energy scene until recent years.

The diversity of these environmental effects and their causes greatly complicates the formulation of remedial measures on the development of technology that will contribute less environmental impact at the outset. A number of considerations that bear on this problem are discussed in the sections that follow.

1. Intermedia Impacts of Pollution Control Strategies

a. Introduction

The characteristics of the physical environment are such that each component is intimately interrelated with every other component. As a result, present and potential environmental problems in a number of categories facing the nation are interrelated through their effects on the adjacent environment. A prospective solution to any one environmental problem must take cognizance of impacts on other activities and other aspects of the environment to avoid contributing to different but equally unacceptable problems. A central factor is that all developments (and modifications to them) represent perturbations to the environment, acting at a pace, on a scale, and in a manner different from those that nature would impose.

Recognition of the interrelationships and cross influences among environmentally important activities is vital to the planning necessary to prevent adverse environmental consequences. In short, it will not do to "solve" a problem in air pollution if the solution leads to impaired water quality or accentuates solid waste disposal problems. Rather than considering separate environmental categories such as air, water, solid waste, or the like, real progress toward improvement of environmental quality requires viewing the environment in its entirety.

b. Discussion of the Problem

In response to public concern, the federal government has moved to deal with problems of air pollution, water pollution, management of solid wastes, and other aspects related to environmental quality. Recent activity in dealing with environmental problems has emphasized individual categories of the environment, and organizational emphasis has been given to this approach.*

No technical reason is apparent for dividing the physical environment into such categories. In fact, from a scientific standpoint, they represent a return to the description of the physical world in terms of four "elements"--air, water, earth, and fire. Only the latter element is lacking from the present fragmented approach to environmental problems exemplified by current program patterns.

Perhaps the major drawback in the present approach is that it does not reflect the technical knowledge accumulated in the centuries since the original scientists contemplated the physical world. Actually, it appears to result from a rapid institutional response to deal constructively with expressed public desire to improve environmental quality; this is entirely logical, and represents an encouraging factor at a time when many criticise government for being unwieldy or unresponsive.

The present arrangement of organizations to deal with environmental quality appear to be related to the legislation that established the programs for dealing with pollution in a particular medium, although the legislation may not specify organizational aspects. The creation of the EPA allows for internal reorganization to deal most effectively with environmental problems. The organizational units that execute legislative intent provide the public an opportunity to see that the legislative will is being carried out, and they also facilitate accounting of funds that are appropriated so as to perform the required programs.

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* For example, the Environmental Protection Agency (EPA) has an Air Pollution Control Office and a Water Quality Office to deal with pollution problems in these media.

However, while the present approach provides for simple accounting, it is less efficient in achieving accountability for progress in maintaining or improving environmental quality in any given category because of the interrelationships of environmental media. Although it is important to keep close account of public funds used for environmental purposes, it is even more important that the funds be used in such a fashion to achieve their public purpose. Uncoordinated programs that may be able to achieve individual environmental objectives could have their "success" obviated through the consequences of other programs. In short, environmental discharges cannot be dealt with in a piecemeal fashion; the environment by definition comprises an array of interlocking factors, and governmental programs for environmental quality must reflect this basic principle.

2. Water Pollution Control

a. Introduction

Federal expenditures for water pollution control have increased substantially in recent years as the government has moved to meet the growing concerns of the public for positive actions to safeguard the quality of the nation's water resources. However, in spite of the recent attempts to control water pollution and rising budgets for such programs, many waterways remain significantly polluted. With a long agenda for important social needs and limited funds to address these needs, the public is understandably questioning whether it is receiving benefits commensurate with costs in the water pollution control field.

In the environmental area, it is often possible to measure costs and benefits through an inferential process that relies heavily on data that are of uncertain reliability. Although it is possible to determine costs of projects or facilities and to calculate benefits in savings of effort, a complete balance sheet of environmental costs and benefits cannot be constructed because of the important role of intangible values placed on environmental aspects by individuals or societal groups. Furthermore, it must be recognized that pollution control projects that suggest net benefits in terms of environmental quality may prove to result in net costs to society when considered with economic or other social aspects. In short, it can be and has been shown that all water pollution control projects do not necessarily result in increased benefits to society.

b. Discussion of the Problem

Water pollution from any source is a perturbation to the natural environment. In many areas of the nation, polluted waters have persisted for extended periods of time, while in other areas the present degree of pollution is a relatively recent development. Water pollution is particularly important, since water is the medium for transmitting pollutants to other elements of the environment or to other areas that are not now affected.

While all pollution is a perturbation to the environment, since it involves materials, quantities, and processes that differ from those of nature, it is not often recognized that remedial measures to counteract pollution are further perturbations to the environment, so that not every action achieves its intended result. For example, coal mining has led to acid mine drainage in much of the Appalachian region and adverse effects on ecological and solid factors in that area. However, attempts to neutralize acid waters by addition of limestone have resulted in precipitation of iron hydroxide ("yellow boy") that poses even more difficult problems for pollution control and rehabilitation. The lesson to be learned from this experience and similar activities is that the remedy can be as costly as the malady unless its ramifications are thoroughly understood. Progress in dealing with water pollution control requires clarity in definition of the nature of pollution and the means for its control, comprehension of the benefits as well as the costs from such control, and identification of the parts of society that will enjoy such benefits and that will bear the costs: the two groups are not likely to be entirely identical.

Furthermore, it is necessary to consider several environments, each of which is interrelated:

- The physical environment, which governs the relations of factors and processes.
- The socioeconomic environment, which comprises the actions of man relative to water pollution.
- The institutional environment, which is the system developed by man to regulate his activities.

3. Interrelationships of Land Use Planning and Control to Water Quality Management Planning

a. Introduction

The importance of land use considerations to problems of advance planning in water quality management is a relatively new concept. Unfortunately, the few previous attempts to relate water quality data to land use planning resulted in specialists from both disciplines "talking past but not communicating with" one another. Each group has needs for basic, applied, and interpretative data. A review and evaluation is needed to focus on the work of pertinent water management agencies and major land use planning groups. The aim of such work is not merely to produce a scholarly review and critique of water quality data but also to define the scope and character of information about water resources that land use planning agencies require, according to their needs. It will be especially important to identify the planner's views on the manner and format in which water quality data are compiled, presented, and disseminated. These data will be essential in preparing an outline of features desired in water quality reports for use in land use planning programs. Also, the degree of change of format suggested will be necessary to estimate likely costs of any changes, as well as the time to accomplish improvements.

b. Discussion of the Problem

The recent levels of public concern over environmental quality have led to significant legislation and funding for national programs dealing with pollution control. An especially important program administered by the EPA provides construction grants and loans to qualified local agencies to support installation of improved water pollution control and abatement activities as a part of comprehensive area plans. The program is projected to commit about $2.2 billion in fiscal 1973 and even larger sums in subsequent years.*

The Federal Water Pollution Control Act of 1970 provides for federal grants in aid of municipal facilities for waste treatment and pollution control. To qualify for these grants, applicants must show that their proposed facility is consistent with a comprehensive river basin, regional, or metropolitan plan for water quality management. These plans must be approved by the EPA according to established guidelines before funding can be authorized for individual facilities. The exacting conditions under which these funds can be allocated have led to some difficulty in keeping grants abreast of the planning work and have presented significant difficulties to many applicants. It is said that in at least one region, few applications have been approved recently because federal authorities were not satisfied on the points in question.

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* This program is described in the "Guidelines for Water Quality Management Planning," prepared by the U.S. Environmental Protection Agency in January 1971 in response to 18 CFR 601.32-33 dated 2 July 1970.

In this regard, it is important to bear in mind that water does not pollute itself. Pollution is introduced to waters as a consequence of activities and patterns of use of lands occurring adjacent to waterways. Therefore, meaningful progress in improvement (or even maintenance) of water quality can be accomplished only if the influence of land use is included in the planning process for water quality management. Although necessary, the consideration of interrelationships of land use practices, together with water quality management, represents a break with tradition and could be construed as a threat to important interests. Defining, describing, and explaining the salient elements of the overall planning process will be required to achieve a better understanding of the benefits and problems resulting from this integrated approach on the part of those responsible for day-to-day activities in the land use and water quality area. These elements will be incomplete unless related and interdependent technical, operational, and institutional factors that govern or affect planning can be displayed and clarified to assist responsible officials at all levels in the conduct of action programs for achieving national environmental quality goals.

These considerations suggest that it will be increasingly important to deal with the environmental aspects of energy development to satisfy the mission responsibilities of the DoD. This topic is considered in greater detail in the section that follows.

D. Implications for DoD

As a priority consumer of scarce energy supply, DoD will attract additional scrutiny. Domestic operations planning must take account of the possibility that electric utility service reliability may be locally reduced as demands rise faster than equipment is emplaced to serve them. Several metropolitan utilities have contingency plans for load-shedding during peak demand periods that may have to be implemented. Military installations will be pressed to conserve power use and to avoid on-peak loading of utility systems. If the severity of the energy shortage reaches the stage at which it is necessary to ration civilian consumption of electric power, or gasoline, or both, the immediate impact of priority energy use will be extended to a wider population; and the opportunity to exploit such impact from the standpoint of dissent will be materially enhanced.

The environmental impact of the energy consumption of DoD material suppliers will also come under review. Some of these supplies, such as the aluminum industry, use very large amounts of electric power directly. Other materials of which the DoD is a major consumer--e.g., reactive metals--depend ultimately on electric power for their reduction via an electrowave reducer such as magnesium or calcium. A total environmental analysis of defense procurement, inventorying the air and water emissions and the land uses that result from this production, would be useful to isolate other such areas in which DoD procurement has large, indirect impact. Then a review of procurement specifications--for necessary purity requirements that inhibit scrap recycle, for nonsubstitutable use of high-energy-cost materials, for opportunities to use other substitutions that would reduce the emissions of pollutants or the energy consumption of overall use of material--would assist in planning actions responsive to national needs for mitigation of adverse environmental impacts on the public.

There will be continuing need to take environmental factors into account as the Alaskan oil and oil shale reserves are developed. Holdings of some of these reserves such as Naval Petroleum Reserves and Naval Oil shale Reserves will require the DoD to practice environmental management in their development and, in doing so, to comply with the intent of Environmental Impact Statements prepared for the actions. The decision to develop reserves from which production has not already begun will be a "major federal action" within the meaning of the National Environmental

Policy Act. The release of restrictions on the national fuel supply and, therefore, on economic growth will be held by some as an adverse rather than a beneficial environmental impact.

Sites will be needed for both nuclear and fossil-fuel power plants that allow separation from population centers for absorbing environmental hazard and impact. Land holdings of the DoD--some of which are almost the only remaining open spaces in the midst of urban development--will be sought for these purposes; in the process, DoD will need to justify its use of these lands vis-à-vis other potential public uses.

E. Recommendations for Further Studies

The DoD can be an effective contributor in the role of environmental problem solution. A broad intersection of military and civilian interest in technology is related to energy production, conversion, and transmission. For example, early military interest in spark-ignition engines has already contributed to the stratified-charge engine technology that probably is the basis of eventual solution to automotive air-pollution. The intersection is much broader. Defense-sponsored basic research in combustion is closely related to the root of one serious pollution problem--NO_x. Defense materials technology will be useful in a number of ways in the new fuel conversion plants that may be built to convert the large western deposits of lignite and oil shale to clean, concentrated fuels. Fuel-use and high-energy-density battery needs of DoD and of the civilian sector are very similar. Some scenarios of future urban development see the expulsion of combustion-powered vehicles from big, densely populated urban cores and their replacement with combinations of mass transport systems and utility vehicles powered by yet-to-be developed electrochemical systems. Defense interest in package-power systems may aid in breaking through the technology structure that gives immense economy-of-scale advantage to very large plants and that, in consequence, leads to environmentally objectionable transmission lines and intense local concentrations of pollutant emissions.

The above are examples; a systematic inventory of possibilities would have extensive scope.

An outline for such an inventory would be based on the principal energy-related, environmental problems:

- SO_2--This pollutant, emitted from combustion of both fuel oil and coal primarily, is a major air pollution problem. Solutions entail chemical stripping from stack gases, removal from fuels, and conversion of oil and coal to methane and lighter hydrocarbons with removal of sulfur in process. High temperature, high pressure process technology, heat transfer technology, control, and measurement have high transfer potentials.
- NO_x--This is formed in combustion processes using air. DoD combustion research, engine development, and gas analysis methods are potential contributions.
- Particulate-Smoke--This is associated especially with energy conversion plants using low Btu coal, and locally could be a serious adverse environmental factor.
- Heat--Adverse environmental effects result from emission of waste heat to waterways or to air via evaporative cooling towers. Processes to use low-grade waste heat would be of use in environmental protection as well as in resource conservation.
- Fuel handling and distribution--Essentially the need is for care and foolproof, no-spill equipment design and development, as well as improved technology to clean up spills that do occur and rehabilitate affected areas.
- Underwater operations--Underwater oil well completions, perhaps drilling, would offer advantages to development of offshore oil reserves, increased protection from storm and collision damages, and possibly aid in extending the search for fuel reserves to deeper waters.

- Excavation technology--Efficient underground mining methods would alleviate some environmental damage at lignite and shale developments. Tunneling technology would encourage development of efficient, environmentally desirable energy transmission systems and utility systems to make efficient distribution of central heat and refrigeration for both conservation and minimization of pollution.

Both as target and as problem-solver, the DoD's Corps of Engineers is highly visible environmentally. In its traditional role as a builder of flood control and navigation facilities on the nation's waterways, the Corps has attracted considerable environmental opprobrium. Results that once were considered to be unquestioned benefits are now considered undesirable adverse environmental impacts. Moreover, the opportunities for major benefit with minimal environmental perturbation are becoming harder to develop.

The Corps has been largely a rural construction operation. However, the opportunities for environmental improvement by construction are now mainly urban. A great variety of urban needs, ranging from advanced sewage systems to transit, can use the engineering skills represented by the Corps. Major institutional obstacles to filling these needs at present underscore the need for new modes of federal-local interaction; cooperation between private and public institutions--for new forms of utility development, for example; and project decision and planning. Rather than wait for these institutional forms to develop, it seems desirable for DoD to take the lead in institutional obstacle analysis, synthesis of practical solutions, and advocacy of them to better use its skills in meeting the urgent domestic environmental and social needs of the nation.

CHAPTER FIVE--AIR QUALITY

I--AIR QUALITY PROBLEMS--AN OVERVIEW

I AIR QUALITY PROBLEMS--AN OVERVIEW

A. Introduction

The Air Quality Act, as amended (1970),* stipulates the maintenance of "clean air" as a national goal. The President's Executive Order 11507 establishes the Department of Defense policy toward the protection and enhancement of the quality of the environment. At this time, environmental policy is being developed and implemented by the DoD. As in the parallel case of establishing environmental safeguards in the civilian community, many aspects of air pollution can be controlled by the application of existing technologies. As these are being applied, other problems are emerging that require additional study before their solutions can be implemented. Thus the identification of present and future problem areas is the first step in dealing with the situation.

The Air Quality Act directs the Secretary of Health, Education, and Welfare to develop ... "such criteria ... as in his judgment may be requisite for the protection of public health and welfare...." As these criteria are developed, the states are expected to control emissions in such a manner as to maintain the requisite air quality. Implicit in this is the assumption that the relationship between emissions and ambient air quality can be ascertained, taking into consideration the manner in which the pollutants are emitted, dispersed, or concentrated in the atmosphere and how they interact under the influence of oxygen, sunlight, and the like. This requires the acquisition of emission data

*PL 91-190.

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and the establishment and verification of mathematical models relating emissions with ambient air concentrations. Analytical techniques for detection and measurement of gaseous pollutants are generally well developed. Methods for dealing with particulate pollutants are far less adequate. The establishment of inventories and the verification of models are tasks currently under intensive investigation by the Environmental Protection Agency. To date, air quality criteria have been established for only six compounds or classes of compounds: carbon monoxide, hydrocarbons, nitrogen oxides, photochemical oxidants, particulates, and sulfur dioxide.

On the federal level, responsibility for air quality is vested in the EPA, which conducts numerous surveys, sponsors research, and establishes and enforces limits. Similar programs are carried out on the state level by various state boards and sometimes on a county or regional level. The requirement of preparing an environmental impact statement to which all major federal and most state projects are subject provides a means of influencing their direction.

Air pollution problems cut across the entire range of DoD operations from housing installations to manufacturing, transportation, and weapons systems. Increasingly stringent emission controls will have an effect on virtually all operations.

B. Housing

The air mass surrounding the earth is a dynamic, changing system, which is in apparent equilibrium only over short periods of time, geologically speaking. Both geological and biological processes affect it, changing its composition from the oxygen-deficient primeval atmosphere to the present composition of 78 percent nitrogen, 21 percent oxygen, and 1 percent minor constituents. In turn, the composition of the atmosphere affects every living being, and any further changes will affect the biosphere. Only during the last century have human activities reached a level that is capable of producing measurable changes of the atmosphere; but in this short period of time, the carbon dioxide concentration, for example, has risen 14 percent as a direct result of the conversion of fossil fuel to energy.[1]

The characteristics of the waste products of a biological system are determined largely by its source of energy, and this also holds true for human activities. The pollutants produced by a community--a city, a hamlet, or an army installation--are primarily the result of energy generation for heat and power. Thus, the use of high-sulfur coal or fuel oil constitutes the primary source of sulfur dioxide, one of the pollutants for which the EPA has established air quality criteria. Thus, housing facilities of the armed forces share with the civilian community the problem of dealing with this pollutant at the source. Only a few approaches appear possible:

(1) For space heating, the use of low sulfur coal, possibly as the result of a national policy aimed at encouragement of use of sizable western coal resources.

(2) For power generation, the removal of sulfur from either the fuel or the stack gases. Sulfur removal from petroleum products can be achieved readily by established refinery methods; the removal of sulfur from coal presents a far more difficult problem, since only the part of the sulfur present as inorganic sulfur--chiefly pyrites--can be readily removed. Roughly 50 percent of the sulfur is present as organic components intimately associated with coal. Thus, unless coal gasification is practical, removal of SO_2 from stack gases appears to be the most practical method of control of sulfur oxides emitted from coal burning installations.[2] The technology for SO_2 absorption is at present in the pilot plant stage.

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[1]G. S. Callendar, Tellus, Vol. 10, p. 243 (1958).

[2]J. C. Dons, "Sulfur Removal," Chem. Eng. (June 1972).

(3) The use of tall stacks for generating plants constitutes a means of controlling ambient concentrations, although it does not reduce emissions. The overall effect of tall stacks on regional (rather than local) air masses and ground concentrations outside the local area is not well known.

Alternative methods of space heating using central power plants should be reevaluated in the light of the better controls applicable to power plants. Distribution of energy in the form of hot air, steam, hot water, or electricity should also be considered as part of a "total energy concept."

The disposal of solid wastes constitutes another aspect of housing problems that interfaces with air and water pollution. Currently, land fill is the favored method of disposal, where land is available. Open burning dumps, which contributed greatly to air pollution, have been generally prohibited. However, land for sanitary fills is not always available, and incineration in a well designed facility offers the advantage of a 1 to 10 reduction in volume of the wastes. EPA is investigating the possibilities of recovery of fuel gas (by pyrolysis of the waste materials) or simply energy (heat) from incinerators.

C. Transportation

Ground transportation in the form of cars and trucks are the primary source of several important pollutants, such as carbon monoxide, hydrocarbons, oxides of nitrogen, and lead. Here again the DoD shares in the production of these pollutants.

A great deal has been written lately about the role of the internal combustion engine as a contributor to air pollution. First generation control technology is available for all these emissions. The DoD is in a particularly favorable position to evaluate some of the proposed methods under controlled conditions, such as the effect of low lead and lead free gasoline, the importance of tune-ups and engine modifications as, for example, engine timing. Since the automobile is estimated to contribute as much as 80 percent of the carbon monoxide, most of the man-made hydrocarbons and lead, and an important share of the oxides of nitrogen, the reduction of emissions from automobiles constitutes an important aspect of local environmental air quality control. On the other hand, the long range effect of the various control strategies on the efficiency of fuel consumption by automobile engines is not well known. Controlled tests at DoD installations could provide some answers important for conservation of fuels that are in short supply.

An alternative approach is the development of different engines. Here a wide range of possibilities exists, from modifications of existing piston-type engines such as stratified charge engines to other internal combustion engines like gasoline turbines and Wankel engines. Beyond these areas lie the possibility of developing electrically driven vehicles, hybrid power plants using external combustion engines in conjunction with DC generators, accumulators and motors, and fuel cells as primary sources of electrical energy. All these promise to provide substantially lower levels of pollutant emissions than are now possible. However, their development appears to be several years in the future.

The contribution of airplanes to air pollution is not well known, although it is considered to be minor.[3] However, it is heavily localized, at least at ground level. Studies are now going on to determine the emissions from jet engines under a variety of conditions. The emission of particulate material (soot) from such engines has been largely eliminated by redesign of the combustion chamber, but just as in the case of

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[3] R. V. Ayres and R. P. McKenna, <u>Alternatives to the Internal Combustion Engine</u>, Johns Hopkins University Press (1972).

CHAPTER FIVE--AIR QUALITY
II--ATMOSPHERIC CONTAMINATION

II ATMOSPHERIC CONTAMINATION

The testing, development, and operation of weapons systems frequently result in the release of compounds to the atmosphere that, in sufficient quantity or persistence, could result in atmospheric contamination. These effects may be localized in association with specific testing programs or could be widespread stemming from global operations of aircraft or other vehicles.

As examples of the types of influences on the atmosphere that are included in this category, this section contains discussion of three separate activities that could influence the condition and quality of certain aspects of the atmospheric environment. These topics are intended as examples of areas of concern to illustrate the nature of activities deserving future attention and advanced research.

A. Distribution of Hydrogen Chloride Produced by Solid-Fuel Rockets

1. Statement of the Problem

Hydrogen chloride is a major component in the exhausts from solid-fuel rockets using perchlorate oxidizers. It combines with water to form hydrochloric acid, which can be deleterious to crops and property as well as to the health of people if it precipitates over agricultural or urban areas. A capability to monitor the distribution of HCl as it diffuses and drifts away from the flight path is important for assessing the effects of rocket launches on surrounding areas.

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2. State of the Art

The distribution of HCl can be monitored by airborne sampling techniques. This process is both slow and expensive, and sampling systems present problems due to HCl absorption on surfaces.

A computer model has been developed that generates concentration contours as a function of time after launch for the existing meteorological condition and the rate of injection of HCl along the flight path. This model is useful for prelaunch predictions of hazards and for postlaunch estimates of the actual distribution. However, the model is not an adequate substitute for actual three-dimensional monitoring of the distribution of HCl. It also seems doubtful that this model, even in combination with post-launch airborne sampling, would provide acceptable evidence for formal inquiries into damage complaints.

3. Present Activities and Organization

Both the Air Force and NASA are concerned about the HCl problem for launches from Cape Kennedy and Vandenburg. To the best of our knowledge, there are no instrument development programs to overcome the difficulties.

4. Implications for DoD

Accusations of damage attributable to fallout of hydrochloric acid generated by rocket launches could create a problem for the Department of Defense. At present, there is no high-confidence method for assessing the validity of such accusations nor of proving to a board of inquiry what conditions actually existed in the geographical area of concern.

5. Recommendations for Further Studies

Hydrogen chloride has absorption bands in the infrared region between 0.8μ and 4.8μ. Optical parametric oscillators for this spectral region have recently been developed. It is likely that enough energy could be generated to make feasible an optical radar, or lidar, for remote measurement of the post-launch distribution of HCl over an extended area. It is recommended that a development program for such an instrument be undertaken.

Another problem that requires further study is the rate at which HCl combines with water in the atmosphere, both in the liquid and gaseous phases. Methods for measuring or inferring the fraction of HCl that combines with water and other aerosols should also be investigated.

B. Upper Atmosphere: Possible Effects of High Altitude Contamination from Rockets

1. Statement of the Problem

Numerous government agencies are conducting research programs, performing operational tests, or conducting routine operations that directly or indirectly modify the composition of the upper atmosphere. This modification may be incidental to a given mission, such as the operation of rockets through this stratum resulting in the deposition of large quantities of combustion products and unburned fuel. In other cases, the changes wrought are designed to gain information either on the natural environment or the specific perturbation induced. Examples range from chemical releases and electromagnetically induced ionospheric heating to high altitude nuclear bursts. While some of these activities are either sporadic or temporarily held in abeyance, others are continuing operations expected to persist. From studies of other planetary atmospheres as well as our own, there is reason to suspect that the balance of constituents in the atmosphere, and the incredibly complex interactions with the various radiations from the sun in particular and space generally, may have a direct and very precarious effect on conditions at the earth's surface.

The effects of man-made perturbations on the upper atmosphere need to be assessed, and indeed the natural environment itself must be studied and understood to arrive at a comprehensive assessment of changes expected. There is a concomitant need to assess the repercussions that would occur if certain activities were to be curtailed or appropriately modified to lessen the effect on the upper atmosphere and to develop an acceptable scheme for evaluation of the trade-offs indicated.

2. State of the Art

Until recently, all knowledge of the upper atmosphere (above 100 km) has been obtained by ground-based indirect methods. For example, the ionized layers of the upper atmosphere have been probed by sending radio signals skyward and examining the reflections. But since 35 km constitutes the upper limit of balloon travel, no direct, in situ measurements were possible. Only since 1945, when the first WAC Corporal was fired at White Sands Proving Ground, has the exploration of the upper atmosphere been possible. Sounding rockets made possible direct measurements of atmospheric conditions, which led to the detection of x-rays and auroral particles; to the first photographs of the solar ultraviolet spectrum; and to the gathering of data on pressure, temperature, density, and composition of the atmosphere. Since these altitudes are too low for stable satellite orbits, the sounding rockets have remained the most important research tool.

free gasoline, the importance of tune-ups and engine modifications as, for example, engine timing. Since the automobile is estimated to contribute as much as 80 percent of the carbon monoxide, most of the man-made hydrocarbons and lead, and an important share of the oxides of nitrogen, the reduction of emissions from automobiles constitutes an important aspect of local environmental air quality control. On the other hand, the long range effect of the various control strategies on the efficiency of fuel consumption by automobile engines is not well known. Controlled tests at DoD installations could provide some answers important for conservation of fuels that are in short supply.

An alternative approach is the development of different engines. Here a wide range of possibilities exists, from modifications of existing piston-type engines such as stratified charge engines to other internal combustion engines like gasoline turbines and Wankel engines. Beyond these areas lie the possibility of developing electrically driven vehicles, hybrid power plants using external combustion engines in conjunction with DC generators, accumulators and motors, and fuel cells as primary sources of electrical energy. All these promise to provide substantially lower levels of pollutant emissions than are now possible. However, their development appears to be several years in the future.

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[3]R. V. Ayres and R. P. McKenna, Alternatives to the Internal Combustion Engine, Johns Hopkins University Press (1972).

the automobile, certain trade-offs are inherent in these modifications: the elimination of incompletely burned fuel by better combustion chamber design probably increased the emission of oxides of nitrogen, potentially a more harmful, if less visible, pollutant.

Not all emissions from airplanes take place at ground level, although idling and taxiing is conducive to high local emissions. Combustion products within the troposphere are well dispersed and usually rapidly removed through meteorological interactions. Stratospheric flights present a new dimension of air pollution because of the absence of mixing effects, resulting in long residence times. The emission of oxides of nitrogen is of particular concern because of its possible effect on the ozone layer. Studies of possible effects of flights at these altitudes are of considerable interest.[4]

D. Manufacturing

The DoD controls a variety of manufacturing activities under the direction of the Material Commands. Considerable effort and funds are allocated to air, water, and noise pollution. For example, Natick Laboratories has an extensive program on biodegradation of waste material; the Mobility Equipment Command is concerned with engine emissions, fresh water procurement, and waste water treatment; the Munitions Command is addressing itself to the reduction of oxide of nitrogen emissions and disposal of unusable explosives; the Coating and Chemical Laboratory is developing improved cleaners and specifications for fuels, such as gasoline, as does the Fuels and Lubricants Research Laboratory.

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[4] H. Johnston, "Reduction of Stratospheric Ozone," *Science*, Vol. 173, p. 517 (1971).

All these activities have facets that bear directly on air and water pollution. Because of the enormous variety of materials handled, only a detailed examination of each product area can provide the necessary information to control that environmental impact. For example, SRI developed the list of data shown in Table I-1 as a basis for evaluation of possible air pollution at munitions plants. Similarly detailed investigations are required in other areas of possible environmental impact, as noted in Chapter Four.

E. Weapons Systems

Although the preservation of air quality is not a primary consideration in the design of weapon systems, their testing and deployment sometimes require certain environmental considerations. The best known example is certainly the ban on atmospheric nuclear testing. The decision to discontinue the development of chemical and bacteriological warfare agents similarly removes a threat to environmental quality; their disposal, on the other hand, creates a different problem, since the old practice of ocean dumping is no longer acceptable. Chemical detoxification and incineration under carefully controlled conditions appear to be usable methods of disposal.

In another area is a somewhat more localized, but nevertheless real, impact on the environment from the testing and firing of large rockets. There are about 35 U.S. space launchings per year and many more test firings of ICBMs, ground-to-ground missiles, and small satellites. A good many of these use solid propellant motors, which can produce high local concentrations of hydrochloric acid near ground level. Similarly, the effects of the many species generated in rocket exhaust on the upper atmosphere are only insufficiently known and need to be delineated more clearly.

Table I-1

DATA REQUIRED FOR EVALUATION OF AIR POLLUTION ABATEMENT AT MUCOM MUNITIONS MANUFACTURING PLANTS

Data on Each Process Emitting Pollutants

(1) Process flowsheet and description including operating conditions (temperature, pressure, flow rates of process streams)

(2) Material and energy balances

(3) Utility requirements (including fuel, steam, electricity, process water, cooling water, refrigeration, etc.)

(4) Characteristics of fuel used

(5) Flow rates of process offgas and of process ventilation air. Conditions of gas and air flow (temperature, pressure, water vapor content)

(6) Alternative changes in process that would reduce or eliminate emission of pollutants

Data on Pollutants Emitted from Each Process

(1) Kinds and amounts of each pollutant emitted (by process stage)

(2) Concentration of pollutants in gas or air streams

(3) Methods used for measurement of pollutant concentrations

(4) Value of pollutant material, if any

(5) Characteristics of pollutant material (if not a single, distinct chemical compound)

Data on Existing Air Pollution Control Equipment and Systems

(1) Description and specifications of equipment

(2) Operating conditions of control equipment (e.g., gas pressure drop, water circulation rate)

(3) Utility requirements (electrical power, steam, water)

(4) Chemical and raw material requirements (e.g., alkalis for absorption of acid gases)

(5) Concentration and total quantities of pollutants entering and leaving control system

Table I-1 (Concluded)

(6) Capital and operating costs of control equipment and control system

Data on Proposed Control Systems

(1) Results of laboratory or pilot plant studies--operating conditions and performance

(2) Design of proposed control equipment system

(3) Estimated utility requirements and other operating costs for proposed system

(4) Estimated capital costs

(5) Estimated schedule for acquisition, installation, and operation of control system

3. Present Activities and Organizations

Since the atmosphere forms a continuum, many investigations carried out in the stratosphere or near space overlap the upper atmospheric region. Conversely, the possibility exists that the weather in the troposphere may in some way be affected by changes occurring in the ionosphere. Many properties of the ionosphere are of profound importance to certain properties at ground level: for example, electric currents flowing in the ionosphere are responsible for changes in the earth's magnetic field and affect the guidance of space vehicles. As a consequence, continuing programs are carried out by NASA and other government agencies in this region.

4. Implications for DoD

While sounding rockets and occasional space vehicles traversing the upper atmosphere are likely to have only a minor effect, other activities were designed to produce measurable effects. Detonations, using both conventional and nuclear burst, have been carried out to study the response of gases to large impulses of short duration. The ejection of sodium vapor has permitted the measurement of its radiation and its diffusion. The injection of electrons into the upper atmosphere were carried out to further our understanding of the trapping of charged particles.

Increasing concern for the environment, as reflected by recent legislation and several Executive Orders, makes it imperative that DoD examine potential implications of operations in the upper atmosphere. The necessity derives not only from environmental policy but also from a need to assure orderly development of defense systems.

5. Recommendations for Further Studies

There is a need to evaluate the long range effects of alterations of the upper atmosphere, since the absence of a mixing mechanism (other than diffusion) creates very long residence times. This includes not only such changes as mentioned above but also the possible effect of the relatively large concentrations of combustion products (from rocket exhaust) on the properties of the upper atmosphere. The possible effect of such combustion products on absorption or transmission of radiation, which could have a secondary effect on the stratosphere ozone layer, should be examined.

C. Potential Impacts of High Altitude Emissions from Aircraft

1. Statement of the Problem

The possible adverse effects of extensive aircraft traffic in the stratosphere has recently become the subject of much concern and considerable study. When the potential problems were first considered, as reported in the SCEP report (1970),[1] the jet engine emissions into the stratosphere of possible concern were believed to be water vapor, particulate material, hydrocarbons, nitrogen oxides, CO_2, SO_2, and CO, in that order.

In 1971 H. Johnston[2] pointed out that nitric oxide (NO) emissions were by far the most serious jet engine emission into the stratosphere. Nitric oxide reacts rapidly with ozone (O_3) to produce NO_2, which photolyzes at a rapid rate to regenerate NO. Thus, NO is actually a catalytic promoter of the O_3 destruction reaction. The only significant sink for NO in the stratosphere is the nitric acid (HNO_3) formation reaction. Nitric acid has been observed at a concentration of about 5 ppb, as reported by Murcray (1969),[3] indicating the possibility that the HNO_3 formation reaction is significant. Johnston, on the other hand, has made calculations showing that an increase of NO concentration of 30 ppb would reduce the stratospheric ozone concentration by a factor of 2. This would have profound physiological effects on man and on other life forms on earth.

Water vapor and particulate emissions into the stratosphere could also have deleterious effects on the earth's climate by absorption and scattering of solar energy. Present views are that too little particulate matter would be emitted to have much effect, and that the water vapor concentration in the stratosphere could be doubled without serious climatic effects. Nevertheless, measurements to confirm these views have not been made.

The other potential pollutants of the stratosphere are CO_2, CO, SO_2, and hydrocarbons. The quantities injected and the specific reactivities of these pollutants lead to the conclusion that they should probably have no serious effects. However, experimental confirmation of this conclusion also remains to be accomplished.

2. State of the Art

A number of instruments suitable for operation aboard balloons and aircraft are available, and others are under active development. It is believed,* however, that there are a number of serious instrumental deficiencies.

A laboratory capability to measure NO and O_3 in sample chambers by using a chemiluminescent technique has been demonstrated. A single prototype of an NO detector for airborne use constructed at NASA-Ames is now being evaluated. There are some problems, and achieving adequate

* Additional investigation is in progress to establish and document these deficiencies.

sensitivity may prove especially difficult. Airborne O_3 instrumentation technology is well developed and would cause no problems in a measurement program.

Measurement of water vapor at the ambient levels in the stratosphere encounters many difficulties. Sampling techniques are generally in poor repute because of the adverse effects of the walls of the sampling system on the accuracy of the method.

Recent evaluation (by SRI investigators under a NASA contract) of a recently introduced quartz crystal hygrometer indicated that its measured values were also subject to wall effects. Dr. Peter Kuhn of NOAA is using passive infrared radiometers aboard aircraft and balloons to measure the transport of water vapor from the troposphere into the stratosphere. Other radiometers to measure absorption of solar and terrestrial radiation by water vapor have also been used. The sensitivity of these methods has not been ascertained, but their adequacy for measurement of stratospheric water vapor is in some doubt.

Balloon-borne optical nephelometers to measure the concentrations and size distributions of particulate matter are available and allegedly work well. Ground-based lidars have also been used to measure vertical profiles of the concentrations (but not the size distributions) of aerosols in the stratosphere. Airborne instruments for measuring NO_x, CO, CO_2, and SO_2 have recently been constructed. The CO and CO_2 instruments are nearly satisfactory for automatic operation, but more development will be necessary for the airborne NO_x and SO_2 monitors. No satisfactory airborne hydrocarbon monitor has yet been developed.

A more general deficiency of existing capabilities for measuring stratospheric constituents is that data can be collected only along

the flight paths of the balloons and aircraft that carry the instruments.*
The U-2 type of aircraft has an operating ceiling of about 70,000 feet which is somewhat lower than the desired maximum altitude. Balloons can achieve the desired altitudes but provide very limited area coverage. Balloons are also slow, expensive, and difficult to launch, and they cannot be launched at all except under very favorable weather conditions. Recovery of the instrument packages is also expensive and time-consuming, and they are too costly to be considered as expendable.

It thus appears that existing instruments are inadequate to fulfill the needs for determining stratospheric ambient conditions and the effects of jet engine emissions. Sensitivity, accuracy, data rate, and coverage volume should all be improved.

3. Present Activities and Organization

The only current program of significance addressed to the stratospheric pollution problem is the Climatic Impact Assessment Program (CIAP) being carried out by the Department of Transportation. This is an ambitious but probably inadequately funded three-year program to determine through a variety of experimental and analytical processes the ambient conditions of the unperturbed ionosphere, the natural variabilities of these conditions, and the effects of aircraft operating in the stratosphere. The principal means for collecting experimental data are instrumented balloon and aircraft flights supported by ground-based lidar observations of particulates. Improved sampling instruments for measuring NO and water vapor concentrations are being developed under this program, but how well they will perform remains to be determined.

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* This does not hold for optical instruments that determine column content by measuring absorption of light. These can sometimes be scanned to provide "slices" through regions of interest, but the data cannot be resolved in range.

The CIAP effort is good as far as it goes, but the funding limitations and the instrumental deficiencies described above will likely prevent the program from achieving the principal objective. It seems doubtful that SST advocates, environmentalists, and the scientific community will all accept the results as definitive and conclusive. A much more extensive set of measurements based on greatly improved instrumentation will be needed.

4. Implications for DoD

The commercial SST program is no longer an active effort, and operation of the Concorde within the United States and across the North Atlantic is at least a few years away. However, the U.S. Air Force and Navy have ongoing programs to provide B-1 bombers and the F-14 and F-15 aircraft in the relatively near future. These high-performance vehicles will not normally operate in the stratospheric region of greatest environmental concern. Even so, the burden of proof regarding environmental impact in this region could possibly be placed in part on DoD. If the preceding assessment of the results of CIAP proves to be correct, then a well-conceived and adequately funded measurement program to finish what CIAP has begun would be desirable for DoD.

5. Recommendations for Further Studies

This measurement program should provide accurate data on the normal distribution and natural variability of the stratospheric constituents of interest and on the effects of injecting known quantities of jet engine exhaust products into stratospheric regions. This cannot be accomplished without developing improved instrumentation.

Although some improvements in the existing types of instruments can probably be obtained, a technical breakthrough capable of providing really significant improvements is desirable. Recent developments in tunable dye lasers and optical parametric oscillators (OPOs) are likely to provide the foundation for such a breakthrough. The tunable dye lasers provide signal sources for remote measurements at visible and near-ultraviolet wavelengths, and OPOs provide a similar capability in the infrared. In combination with state-of-the-art optical receivers and data-collection systems, these signal sources offer an optical radar, or lidar, capability for remote, range-resolved measurements of all the stratospheric species of interest.

References 4 and 5 describe these capabilities in some detail. Briefly, gases can be identified and their concentrations determined by measuring fluorescence excited by incident laser radiation, by measuring the backscattered energy produced by the Raman effect, or by measuring the differential absorption at two adjacent wavelengths using energy backscattered to the receiver by aerosols or atmospheric gases along the line of sight. The sensitivity and range achievable with each of the three methods depend on such factors as concentration, operating wavelength, and the spectral properties of the gases of interest. Generally, the Raman technique is limited to large concentrations at short ranges because of the extremely small cross sections for Raman scattering.

Lidar instruments capable of measuring the stratospheric gases of interest could be installed in conventional, present-generation jet aircraft and used to monitor the stratosphere from altitudes of the order of 40,000 feet. The available spatial coverage would be enormous; in fact, one flight of several hundred or a few thousand miles would provide much more data than the entire CIAP. A feasibility study followed by instrument development and an extensive flight test program are recommended.

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CHAPTER FIVE--AIR QUALITY
III--REGIONAL AIR QUALITY STUDIES

III REGIONAL AIR QUALITY STUDIES*

A. Statement of the Problem

The general problem addressed in regional air pollution studies is determining cause and effect relationships both between emissions and air quality and control strategies and air quality. The immediate goal is to model these relationships. However, the problem is exceedingly complex, and the solution depends on knowledge of two types--atmospheric phenomena acting on pollutants and effects of air pollutants on the environment of the region--and on techniques of sensing and collecting air pollutant data. The regional study attempts to correlate and integrate the knowledge gained through analysis of field data so that valid models can be constructed and conclusions can be reached concerning how to ensure or improve the quality of the air in the region. The requirements for improving both knowledge and techniques are discussed below.

1. Atmospheric Phenomena

Air pollutants emitted (often from multiple, heterogeneous sources) are transported, diffused, transformed, and removed from the

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* In preparing this section, much use was made of a report given at the Chemist-Meteorologist Workshop held in Ft. Lauderdale, Florida, January 1972, under sponsorship of the Division of Biomedical and Environmental Research of the U.S. Atomic Energy Commission, and published under the reference WASH-1217, UC 4 and UC 53. The A, B, and C discussions in this section contain extensive direct excerpts from the section written by W. B. Johnson and C. R. Hosler (of the Division of Meteorology, EPA, Research Triangle Park, North Carolina) containing the report of Panel IV-- Regional Studies of Atmospheric Pollution from Near-Surface Sources.

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atmosphere. Field experiments and theoretical formulation of the dispersion of airborne materials over short distances, on the order of a few hundred meters, have been carried out for more than 30 years in this country and abroad. However, much more needs to be learned about atmospheric transport and diffusion over longer distances, up to 100 kilometers or so. Interest in these scales has been stimulated by the increasing concern of interurban transport of air pollutants in the growing megalopolis regions of the country. Very little field experimentation has been conducted on air pollution transformation and removal processes.

- Transport and Dispersion--The mean and turbulent structure of the wind field over urban areas must be described to understand urban pollution transport and dispersion. In practice, measurement of the horizontal component of wind is difficult, since it varies in three dimensions and in time, and it is radically affected by location and sensor characteristics. In urban areas such measurements often must be obtained within the "roughness" elements of the city; the "undisturbed" flow may be beyond the reach of conventional wind-sensing techniques.

  Urban temperature fields indicate the potential dispersion characteristic of the urban atmospheric environment; the vertical temperature structure relates directly to dispersion. Thus, the energy exchange process acting on and within the urban temperature excess include urban-rural differences in the thermal characteristics of the surface, evaporation rates, heat produced by artificial sources, and the long-wave radiation balance between the surface and polluted layers in the urban atmosphere.

- Transformations in the Atmosphere--The role of such meteorological variables as solar radiation, temperature, and humidity is not known satisfactorily relative to the creation of secondary pollutants such as photochemical smog products and sulfuric acid droplets. The transformation of gases by photochemical and catalytic reactions and the possible formation of other pollutants by these reactions, is an important factor to be considered in the overall assessment of atmospheric effects on the ultimate disposition of airborne pollutants. However, reaction rate constants in the atmosphere are generally not known. In addition, the effect of atmospheric turbulence on reaction rates in a heterogeneous mixture is not well understood.

- Removal Processes--Deposition or removal of pollutants from the atmosphere affects the earth's surface and may lead to contamination problems affecting natural resources, agricultural crops, and human communities. Examples of such problems have been created by the deposition of radioactive isotopes, biologically active insecticide and herbicide residues, and industrial wastes, to name a few, on scales ranging from local to global. The scavenging or deposition process has three phases, following the delivery or transport phase: (1) in-cloud scavenging by cloud elements, usually termed rainout; (2) below-cloud scavenging by precipitation, called washout; and (3) dry deposition such as gravitational settling and impingement, molecular diffusion, absorption, and electrostatic effects. At present, even the most sophisticated theoretical models do not fully explain the removal processes involved nor have such models been tested in the natural atmosphere. Until experiments are conducted to evaluate and verify existing theories of removal processes, development of more realistic air quality modeling techniques will be limited.

2. Effects of Air Pollutants

The potential cumulative effect of pollutant emissions contributing to a possible global climatic change, through an increase in atmospheric CO_2 content and/or particles, represents a geophysical effect of potentially great importance. However, with respect to regional dimensions there are other more direct and less widespread climatic or geophysical effects of pollution which are long term and appropriate for consideration. Examples are the reduction of sunlight and visibility in major urban areas and the possible changes in precipitation amounts and distributions downwind of certain industrial complexes and urban centers. These regional and localized long term effects have immediate impact on public welfare, but our knowledge of them is inadequate for appropriate consideration in environmental planning and long term control strategies.

3. Sensing and Collecting Air Pollutant Emission Data

Techniques for sensing and collecting air pollutant data include measurement devices, as well as site selection and collection of data sources.

- Aerometric Measurement Devices--Three-dimensional measurements of both appropriate meteorological parameters and air quality are required data for model evaluation. Hence, a capability for horizontal and vertical profiles of pollutant air concentrations and meteorological variables within the planetary boundary layer (1-2 kilometers), is important to achieve. In addition to adapting or modifying conventional sensing or sampling devices to airborne platforms, such as aircraft or balloons, the rapidly developing technology of remote or indirect sounding systems appears promising for regional studies, particularly for the sensing of meteorological parameters, for which several operational prototypes (lidar, acoustic radar, radiometry) currently are being tested.

  However, regardless of the sensing techniques used, local effects of pollutant and heat sources and aerodynamic distortions of flow must be minimized through an initial judicious selection of sites for measurement. The appropriate heights above ground, distances from buildings, traffic, etc., must be selected to provide the desired data for meeting program objectives. In essence, the data acquisition system must ensure that a detailed mapping of meteorology, air pollutants, and emissions can be obtained on time-space scales compatible for the evaluation and verification of air quality models and selected control strategies.

- Collecting Data on Sources of Air Pollutants--The improvement of the accuracy of air quality models critically depends on the adequacy and detail of emissions data. To calculate or forecast short-term concentration distributions requires emission rates that accurately represent hourly and daily variabilities. Source distributions must also be obtained for the less abundant pollutants, e.g., lead, hydrogen sulfide, and other pollutants that may be considered hazardous. A complete areawide source inventory, including point and area sources, will be required. It will be necessary to supply routine emission data of sufficient definition to satisfy modeling requirements and to evaluate the effectiveness of control strategies.

A serious problem in model evaluation is generally encountered in comparing calculated area-mean air quality concentrations with concentrations observed at a point. In this regard, increasing attention is being given to observational techniques for obtaining line- or area-mean concentrations, or for simulating such averages through "clusters" of relatively closely-spaced point measurements.

In addition, there are often incompatabilities between the time averaging involved in observations and in model calculations. Many models consider one-hour averaging to be the finest time resolution that is appropriate or practical, and calculate longer-term mean concentrations by averaging a number of hour-average values. Available instruments vary widely in their time response, and this characteristic should be carefully considered when planning experiments for model evaluation purposes. Studies of certain fast-acting pollutant transformation processes may require measurements with time averaging on the order of seconds, rather than hours.

The need for a concerted atmospheric-pollution study of "sub-synoptic" dimension has been the subject (directly, or in part) of a number of study groups in recent years. Notable among past proposed blueprints and recommendations are those documented in the following:

(1) "The Atmospheric Sciences 1961-1971," report to the Special Assistant to the President for Science and Technology by the Committee on Atmospheric Sciences of the National Academy of Sciences; by Petterssen et al., 1962.

(2) Report of the National Task Group for Mesometeorology to the Interdepartmental Committee for Atmospheric Sciences, by Swingle et al., 1963.

(3) Report of the NCAR Meso-Micro-meteorological Facility Survey Group, by Panofsky et al., 1964.

(4) "Mesometeorological Research and Development Prospectus," report to the Interdepartmental Committee for Applied Meteorological Research, OFCM-67-2, Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, D.C., March 1967.

(5) "A Supplement to Cleaning Our Environment; The Chemical Basis for Action," Priority Recommendations by the Committee on Chemistry and Public Affairs and the Committee on Environmental Improvement, American Chemical Society, 1971.

Relative to the problems of environmental management of our air resource, the fact that the pollution envelope of a single city has never been studied in detail represents one serious shortcoming in our understanding. Past and current token studies in various cities suffer from insufficient data dictated by insufficient resources allocated to the problems. As pointed out by the American Chemical Society's report (Reference 5 above), the following deficiencies exist:

> "... No air pollution monitoring project to date has included a sufficiently dense network of monitoring stations to permit tests to be made as to the minimum number of stations required to characterize the pollution in the city being studied. No study has included enough stations downwind of the city proper to determine definitely the range of influence of pollution from the city on the surrounding area. Meteorological support has never been complete enough to permit judgments about the preferred orientations of buildings to minimize the trapping of pollutants in their lee, or to determine the range of distances in which buildings must be considered separately rather than as statistical roughness elements in groups of buildings. Finally, despite the accumulation of presumptive evidence, no study has been designed specifically to demonstrate the effect of pollutants and heat from a city on weather, either within the city or in the region downwind."

B. State of the Art*

Both implicitly and explicitly, the Air Quality Act as Amended (1970), accepts the premise that air quality improvement can be planned scientifically. Specifically, it presupposes that emission standards can be set by reference to the desired ambient air quality standards, taking into account the manner in which the combined products of various sources in any particular area are dispersed or concentrated by physical, chemical, or meteorological processes. Following its announced policy of emphasis on enforcement, the Environmental Protection Agency is aiding state and local agencies to develop strategies to ensure compliance with such air quality standards as have been set. EPA is also following a policy to extend control procedures to achieve improved air quality standards as they are specified.

This overall concept will fail or succeed to the extent that the basic premise is true. Can air quality improvement be planned scientifically, at least to a useful degree, with existing knowledge and capabilities. If not, what is lacking? By what time can any shortcomings be rectified? The procedures, such as developing Implementation Plans called for under the Air Quality Act (or of filing Environmental Impact Statements under the National Environmental Policy Act), take for granted that existing knowledge and capability are at least minimally adequate for planning. Those who challenge this belief feel that all that can usefully be done at the present time and in the near future is to reduce all emissions to the minimum possible within the state of the art, regardless of any postulated requirements to meet what they may consider to be artificial air quality standards.

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* Extracted from RAPS Prospectus by Standord Research Institute (1972), as published in the AEC report cited.

In either case, it is clear that room exists for considerable improvement in the knowledge and capability that are necessary for confidently relating cause and effect both between emissions and air quality and between control strategies and air quality.

There also can be no doubt as to the value of such a capability. Without such a basis, intelligent direction cannot be given to improving the state of the art of emission control; nor can correct decisions be made between alternatives in control strategies that do not depend on emission suppression and in allocating priorities and assessing cost-effectiveness in either case.

C. Present Activities and Organizations

The following current and planned projects are relevant:

Current

- St. Louis (Project Metromex)--Project Metromex is a cooperative effort by the Illinois State Water Survey, University of Chicago, Argonne National Laboratory and the University of Wyoming. Since the inception of the program about 1969, several other groups have joined the effort for selected field studies. Most of the support to the various research efforts is provided by the National Science Foundation. Other agencies providing support include the AEC, EPA, and DoD.

  The Metromex program consists of cooperative research programs seeking four goals:

  "(a) To study the effects of urban environments upon the frequency, amount, intensity, and duration of precipitation and related severe weather;

  (b) To identify the physical processes of the atmosphere which are responsible for producing the observed urban weather effects;

  (c) To isolate the factors of the city-complex which are the causative agents of the observed effects;

  (d) To assess the impact of urban-induced inadvertent weather changes upon the wide issues of society."

The operational phases of Metromex consists of two parts:

(a) Operation of a network of surface weather instruments, including over 200 recording rain gauges, on a 24-hour per day, year-round basis, beginning in the Spring of 1971 and continuing for five years.

(b) Intensive field studies during several summer months and one month each winter, consisting of surface and aircraft measurement of appropriate meteorological and geophysical parameters and atmospheric constituents. The sampling area, centered on the City of St. Louis, is about 2000 square miles.

Specific research areas include the assessment of weather elements, chemistry of aerosols and rainwater, cloud and precipitation formation, the heat budget, and the modeling of airflow and cloud development. Efforts focus on the convective region.

- Oklahoma City (Boundary Layer Kinematics Studies)--In anticipation of large field programs in mesoscale dynamics and weather prediction, NOAA's Air Resources Laboratory scientists have conducted two series of experiments designed to shed light on boundary layer behavior and to determine the suitability of various proposed methods of making mesoscale boundary layer measurements. The first series of experiments, in Oklahoma City during June 1970, were conducted to develop suitable techniques for collecting serial pilot balloon soundings in the boundary layer which would provide good estimates of the mean wind distribution.

  The second series of experiments was carried out at Oklahoma City in the Fall of 1971, with four distinct goals in mind:

  (a) Compare the mean wind field determined by averaging serial pibal soundings with that determined from fixed instrumentation on a tower;

  (b) Compare characteristics of the wind field (both mean and turbulent) determined from tracking constant volume balloons (tetroons), with the same characteristics determined from pilot balloons, from rapid response sensors mounted at two levels on a tower, and from the slow-response tower instrumentation;

(c) Develop techniques for interpreting the above balloon measurements without comparative observations from an instrumented tower;

(d) Test a procedure developed at the Air Resources Field Research Office, Idaho Falls, for predicting low-level trajectories over mesoscale distances (10-200 km) using a dense network of surface wind speed measurements;

(e) Perfect field procedures for the use of pibal, radiosonde and tetroon techniques to be incorporated into a 1972 Minnesota experiment planned jointly by the Air Force Cambridge Research Laboratories and the British Meteorological Office. (The latter program will include rapid-response measurements of wind and temperature fluctuations at several levels on a short tower, and at several levels on a tethered balloon cable reaching a height of roughly 1500 meters. These experiments are planned to be conducted at a single location in northwestern Minnestoa in the Fall of 1972).

All of these programs are directed toward answering the question of how to make measurements required to treat the dynamics of the boundary layer on a medium scale, i.e., how to appropriately determine all of the terms of the equations of motion, and how to resolve the classical question of the relationship between the wind field, the pressure field, and the stress field induced by the earth's surface.

Planned

- St. Louis [EPA Regional Air Pollution Study (RAPS)]--This ambitious study, to be sponsored by the U.S. Environmental Protection Agency (EPA), will involve a detailed analysis of the sources of pollution, meteorological and chemical processes, and air quality within and near St. Louis, Missouri. The RAPS will require more comprehensive source, meteorological, and air quality data than have heretofore been obtained. The study is expected to take four to five years for completion of the data acquisition phase, consisting of special field studies involving atmospheric tracers, aircraft, mobile laboratories, and remote sensing instrumentation, as well as appropriate continuous/conventional measurement programs.

A detailed management and research plan for the RAPS has been prepared under contract by Stanford Research Institute (SRI). This plan reflects information provided by various participating EPA groups. The SRI RAPS plan will provide guidance and support information to assist EPA in planning and implementing the various research efforts in St. Louis. The preliminary objectives of the four principal tasks in RAPS, as presently considered, are as follows:

(a) Test, verify, and evaluate the capability of mathematical simulation models to describe and predict the transport, diffusion, and concentration of both inert and reactive pollutants over a regional area.

(b) Develop an improved understanding of the chemical, physical, and biological processes that are entailed in determining the concentration of airborne pollutants and the modification of air quality.

(c) Develop a better understanding of factors of significance to the design of improved control strategies in the urban/rural complex, including health and economic effects and the role of land use and community planning.

(d) Develop improved technology that can be applied in local and regional control agency operations, including techniques for emission inventories, air quality and meteorological measurement, data handling and analysis, and the objective assessment of effectiveness.

- St. Louis [NCAR Fate of Atmospheric Pollutants Study (FAPS)]--The objective of this research by the National Center for Atmospheric Research (NCAR) is to determine the extent to which various pollutants are removed from the air by non-meteorological processes, such as chemical reactions, adsorption by plants, adsorption on surfaces, and bacterial action in the soil, and thus are prevented from contributing to regional and world-wide atmospheric pollution. Attempts will be made to establish the magnitudes of the various pollutant sinks, and to develop one or more mathematical models applicable to cities other than St. Louis, and thus to the general question of the role of cities in regional and global air pollution. The research plan calls for three field tests to be conducted before August 1973, when the main study commences. The first experiment was conducted in October 1971 for the purpose of testing equipment, measurement techniques, and data handling methods, and to firm up the overall experimental design.

- Los Angeles and Other California Air Basins (CARB Aerosol Characterization Study)--This experimental program, sponsored by the California Air Resources Board (CARB), has the following objectives:

  (a) To characterize the aerosol in the South Coast, the San Francisco Bay Area, and the San Joaquin Valley Basins in terms of its physical and chemical properties, its interaction in the atmosphere and its natural and anthropogenic origins.

  (b) To evaluate the amount of the atmospheric aerosol in the cited three major air basins which can be related to (1) primary emissions such as from auto exhausts or smokestacks and (2) secondary production due to physical and chemical processes taking place in the atmosphere.

  (c) To identify those major sources of particle and chemically reactive gases which can be related to aerosol pollution and visibility reduction.

  (d) To estimate from aerosol source characterization in the three major regions the extent to which the ambient air quality standards can be achieved by existing technology.

  (e) To evaluate the applicability of the aerosol analysis instrumentation employed in this study for use in present monitoring networks. Special emphasis is to be placed in an improved practical indicator (index) for relating ambient aerosol properties to potential health hazards and to visibility reduction according to established California standards.

  To achieve these goals, extensive instrumentation at both fixed and mobile stations in the three air basins mentioned above will be employed to measure virtually all important characteristics of the atmospheric aerosol, as well as gaseous pollutants and meteorological variables. The field program is scheduled to begin operations during the Summer of 1972.

D. Implications for DoD

Regional studies can produce knowledge and specific technical output useful to DoD. Also, such studies most certainly will afford opportunities for local DoD activities within the region to contribute to the accomplishment of the regional studies. To the extent that the activities of DoD come directly under the provisions and intent of the Air Quality Act as Amended, 1970, or the National Environmental Policy Act, the problem of the effect of air pollutant emissions on air quality on an extended or regional scale is of immediate concern to DoD. Other activities of DoD components, not so directly related to specific national or local regulations but that contain possible effects on the atmospheric environment, should be of equal concern as a matter of policy. Thus, the limitations in current knowledge and methodology that hamper the scientific management of air quality apply to military authorities no less than to all others required to conform with both the letter and the spirit of current legislation. Especially since certain military installations are large operational complexes which concern and extend the surrounding civilian urban developments that support them, their interaction with the local urban concentration is significant both on the local and regional scale.

Apart from the knowledge and improvements in regional scale air quality management techniques that will come from extended area studies as noted above, such studies will provide considerable additional valuable outputs related to air quality monitoring, prediction, and control. Examples are the advances to be made in instrumentation for sensing contamination in low concentrations, techniques for developing automatically operating networks of multiple sensor stations, improved understanding of the chemistry of atmospheric pollution, and improved understanding of atmospheric transport and diffusion processes on all temporal and spatial scales. Some of these outputs perhaps could be used to improve the cost-effectiveness of certain types of military operations; many will be of value in providing improved capability for carrying out operations safely and with minimum adverse effects on the atmospheric environment of DoD activities. Such activities can be of an occasional nature--e.g., rocket launching tests, transport of noxious materials--or of a more routine and continuous nature such as the operation of major airfields, training bases, or military plants.

Concerning ways in which DoD elements could contribute to the studies being conducted or planned, the resources of the various DoD operational and research facilities in a region generally have considerable potential for supporting studies of some of the problems being addressed through multiagency, interdisciplinary effort. Especially, in particular localities such as the St. Louis regional area, a number of military installations and resources could become engaged. Table III-1 lists some of the DoD installations in the St. Louis area that could benefit from and perhaps contribute resources, e.g., sites, aircraft, research facilities, to the St. Louis RAPS program.

The potential for helping also extends over a wide range technically. Thus one can see opportunities, for example, for contributing very specialized resources, e.g., wind tunnels, for conducting appropriate supporting research; or, on the other hand, for making available the records of military hospitals or other medical records for providing etiological data of use in studies of health effects in connection with regional air quality studies.

Studies of special interest to DoD (e.g., meteorological, photochemical) being conducted or planned by local DoD activities in a region could contribute importantly to the regional study basic data, thereby enhancing the models of the region. Also, interaction between regional study personnel and DoD scientific and technical personnel in such disciplines as meteorology and chemisty--both at the local and national levels--could

Table III-1

SELECTED DOD ACTIVITIES IN THE ST. LOUIS AREA

Army

- Granite City Army Depot
- St. Louis Adjt. Gen. Publication Center
  - Active DoD Military Personnel Center
  - DoD Military Personnel Record Center
  - St. Louis Ordnance Plant (inactive installation)
  - Weldon Spring Ordnance Works (inactive installation)
- St. Louis Chemical Plant (inactive installation)
- St. Louis Area Support Center
- St. Louis Ordnance Steel Foundry
- Ft. Leonard Wood
- Army and AF Motion Picture Service
- Army Electronics Command
- Army Materiel Command
- Army Mobility Equipment Command
- Corps of Engineers, St. Louis
- Gateway Army Munitions Plant

Air Force

- Aero Chart and Information Center
- Scott Air Force Base
- Belleville AF Station

Other

- National Cemetery
- V. A. Hospital--Jefferson Barracks
- Lambert Field for Reserve Training
- Aerospace Fuels
- Lambert Field Training

result in increased and timely exchange of knowledge and provide mutual benefit. Attention is invited to the recent announcement* of international cooperation and exchange of knowledge concerning regional air pollution studies. This development may permit DoD personnel additional opportunities to gain better understanding of related foreign technologies if they are engaged in the regional studies.

In summary, the regional air pollution studies have important implications for DoD in terms of direct and indirect gains if the mechanisms of interactions are established at the regional and national level. They also afford DoD the opportunity to contribute actively to solutions of a community problem of which its local operations are an integral part--establishment of viable air quality standards and compliance with those standards. Therefore, it appears vital to DoD's interests to examine ways of interacting with the regional air pollution studies.

E. Recommendations for Further Studies

The extent to which DoD has already become or is planning to become engaged in regional air pollution studies is not known. Therefore, the suggested studies listed below should not be construed as criticism of present DoD thinking. They are offered as steps toward achieving for DoD an appropriate role in the national program of regional air pollution studies. Suggested studies are:

- An inventory by the regions listed in C above of the resources of DoD activities in each region that could contribute to the specific goals of each planned regional study.

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* New York Times, 22 September 1972--Article entitled "U.S. Soviet Pact Sets up Projects on Environment" reports accord reached 21 September 1972 on 30 programs, including a joint project to control air pollution in cities using St. Louis and Leningrad as models.

In particular, Table III-1 should be amplified for the St. Louis RAPS study.

- A survey of all current and planned special DoD air pollution studies to determine their relationship and how they might contribute to the planned regional studies.
- From the results of the above two studies, a study to develop a plan applicable to each regional study that would maximize the mutual benefits to be gained by DoD participation.
- A study to define a long range plan that would represent DoD intent to join the other federal agencies in supporting the local, state, and national programs on a regional basis in their fight against air pollution.

CHAPTER SIX--WATER QUALITY

I--ENVIRONMENTAL IMPACTS OF DOD ACTIVITIES ON WATER USE AND WATER QUALITY--AN OVERVIEW

I ENVIRONMENTAL IMPACTS OF DOD ACTIVITIES ON WATER USE AND WATER QUALITY: AN OVERVIEW

A. Introduction

The increasing attention given to water use and to water pollution abatement and recent federal and local environmental actions have required DoD to consider the impacts of its activities on water quality. Water use and water pollution considerations are pervasive and apply to almost every aspect of DoD activity.

To deal with this challenge, DoD earlier set up a DoD Environmental Pollution Control Committee and more recently has established new positions of Assistant Secretary of Defense for Health and Environment, and Deputy Assistant Secretary of Defense for Environmental Quality. In August 1971, DoD published Directive 6050.1, "Environmental Considerations in DoD Actions," which established guidelines and directives for environmental considerations of DoD activities. One section of this directive dealt in broad terms with the effect of DoD actions on surface and subsurface waters. This section examines selected DoD activities that potentially have important impacts on water use and water pollution.

DoD activities that affect water use and water quality can be conveniently divided into four major categories: (1) construction, land use, and related activities (fixed facilities); (2) hazardous or potentially hazardous military operations; (3) equipment use; and (4) research and development, classified activities, and policy issues.

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B. <u>Construction, Land Use, and Related Activities (Fixed Facilities)</u>

Sanitary wastes emanating from the daily operation of the multitude of military bases scattered through the United States probably have the most significant DoD effect on water quality in this category. These military bases, housing hundreds of thousands of military personnel and their dependents, employing many civilians, covering millions of acres of land, and concentrating populations (sometimes in a very dense manner in urban areas), create sanitary waste disposal problems that in many cases are significant. These problems can be and generally are treated by using current conventional waste treatment methods. An exception is in extreme climatological regions (such as Alaska) where more unique solutions are required because of the characteristics of the climate and of the fragility of the ecosystems.

DoD recognized its responsibility in this area and is attempting to bring all its waste discharges up to federal and local standards as soon as possible. For the period FY68-FY73, approximately $470 million was programmed for pollution control to bring DoD installations into compliance with current air and water quality standards.[1] Areas of ongoing research which can be supplemented in this respect include the following:

(1) Investigation of all potential areas and activities where wastewater can be reused. This will require an inventory of water-using activities to determine the quantity and quality of water required and the manner in which reclaimed water can be used. The Air Force's joint spray irrigation project at Eglin Air Force Base, Florida, appears to be a promising example of wastewater reuse which allowed discontinuation of direct sewage effluent discharges into Choctawhatchee Bay. Other examples of various potential reuse areas are discussed later in the report.

(2) Joint use of wastewater collection and treatment facilities with local municipalities. Many DoD installations are located near urban areas, and therefore the potential for these cooperative activities are widespread. DoD recognized this potential

and in some cases is actually implementing use of various joint facilities. One joint disposal plan that DoD might profitably investigate is the spraying of dilute sludge (from local treatment plants) on poor soils to increase fertility. A large scale experiment of this type is currently being conducted in Muskegon County, Michigan.[2]

More effort is needed in the area of joint facility use, since it can provide economies of scale in both capital cost and maintenance and operation costs for the DoD, as well as for associated municipalities. An inventory is needed for the quantities and types of wastes generated from military installations, current treatment methods, system capacities, and regions of potential joint use with municipalities. The research should investigate activities where military wastes can be held temporarily and released for treatment during off-peak municipal waste periods. This inventory should include not only military installations but also defense related industrial and production facilities such as ammunition and chemical plants. In effect, a comprehensive DoD wastewater management plan that is parallel to current plans under preparation in the civilian sector could be derived from such information.

An additional potential research area concerns the effect of DoD solid waste disposal activities on the environment. DoD is phasing out many of its incinerators and replacing them with sanitary land fills; however, unless land fills are situated and operated properly, they can result in ground water quality problems, especially if the disposed waste has a high moisture content. An inventory is required of DoD sanitary land fill operations to ensure that potential problem areas are identified and corrected before serious ground water quality problems occur. The potential for joint use by municipalities and DoD installations of common solid waste disposal facilities should be concurrently investigated. Recent solid waste handling innovations such as compression and treatment with impervious substances can be investigated also, as well as the potential for recycling resaleable products and generating steam for power or space heating from incinerators. A system (see Reference 2, p. 6-3), developed by Warner Company, Philadelphia, for lining the entire land fill area with a membrane barrier--thus preventing hazardous substances from infiltrating the ground water--has potential for DoD applications. This system provides for collection of the contaminated water for eventual treatment, thus allowing the use of certain sites for landfill operations that otherwise would be unacceptable for ground water reasons. It should be emphasized that pollution of ground water is especially important in that the processes by which natural purification takes place are poorly understood and their relative effectiveness is not well known. Therefore, special attention is required to ensure that DoD activities do not contaminate ground water supplies.

Other methods for disposal and recovery of solid wastes include pyrolysis, compaction, and baling and composting (see Reference 2, p. 6-5 to 6-6). Pyrolysis entails reduction of wastes by baking in an airfree chamber at temperatures as high as 3000°F. Pyrolytic systems are generally more expensive than incinerators and have been used primarily for wastes that were hard to burn. But new air pollution codes may actually make incinerators more expensive than pyrolyzers, since in pyrolysis only the heat source burns in air thus simplifying air pollution controls. Pyrolysis also has the advantage of being able to degrade marginally burnable materials, and it facilitates resource recovery since metals melt to the bottom and burnable fractions can be extracted from the top.

About half of all urban wastes and some industrial waste can be degraded biochemically to a sanitary, humus-like material with little or no odor. Costs typically are in the $8 per ton range before sale of the compost. The major problem with this system is that the potential market usually is not located near urban areas. Another problem is that frequently compost does not have the required nutrients to make it a good fertilizer. This can be overcome by either adding the nutrients before packaging (nitrogen and phosphates) or integrating composting with a sewage treatment process by combining the nutrients from the sewage sludge with the compost. Innovative techniques of this type can probably best be developed under joint arrangements with civilian agencies.

Another potential environmental problem results from DoD's POL* loading, unloading, and transmission facilities and motor pool operations. Every year more than 1.25 billion gallons of used lubricating oil are drained at service stations, motor pools, repair facilities, air fields, and industrial plants.[1] Much of this oil is dumped into landfills or allowed to drain into sanitary and storm sewers, which creates problems because many treatment plants are not equipped to handle this type of waste. Grease and sediment traps and oil separators should be installed on all motor pool operations to separate the oily wastes from the rest of the wastewater. The latter can then be introduced into sanitary sewer systems without too much difficulty. Investigations are needed to determine the applicability of using granular media filters, dissolved air flotation methods, rotary vacuum precoat filters, and American Petroleum Institute separators with an alum treatment to remove oily wastes from DoD effluents.

The technology for recycling oily wastes is rapidly advancing. DoD recognizes the potential for recycling these used oils and is currently investigating the feasibility and economics of recycling. Careful consideration should be given to disposal methods of wastes that are not deemed recyclable, since these can create serious problems for conventional waste treatment plants and can cause ground water quality problems if they are dumped in significant quantities into land fills. The Army

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* POL is the acronym for petroleum, oil, and lubricants.

Mobility Equipment Command's development of mobile equipment for collection and treatment of wastewaters generated at semipermanent or remote facilities has great potential for improved water quality, and this effort should be intensified. Also, much oil is lost or spilled during POL operations and contaminates ground water or surface water supplies. Efforts should be made to install safety devices to minimize these accidents and to train DoD operators in contingency cleanup plans should they occur.

Military construction, like civilian construction, has the potential for creating water quality problems. Unless the construction site is operated properly and revegetated on completion, soil erosion, sedimentation, and pollution can result from large amounts of nutrients introduced into streams and lakes. A temporary mulch of hay, wood chips, or other suitable material will assist in controlling erosion during construction as will quick-growing species of grasses. However, the long term impact of these species is not well known. The production and processing of aggregates should include turbidity control methods such as settling ponds, flocculating processes, and recirculation systems. Spoil materials should be disposed of where the least environmental impact will occur and should be shaped to the topographic features of the area. The pending Sediment Control Act,[3] an amendment to the Federal Water Pollution Control Act, will require states to establish sediment control programs for building and construction activities to include permits, where appropriate, to control land disturbing activities that prevent adherence to water quality standards. DoD should accelerate the process of establishing guidelines controlling all its construction activities.

The Land Management and Forest Management programs of DoD exemplify its concern for preserving federal lands and using them in an ecologically sound way. Continuing efforts are required to monitor these programs to ensure that overgrazing, clear cutting, and other damaging activities do not occur on DoD lands. An EPA-sponsored study[4] has apparently confirmed that pollution increases with stream flow resulting from runoff from the washing of soil, fertilizers, and pesticides in fields and open land in undeveloped, agricultural areas and from various types of pollutants from urban land. Special attention is required in these areas to ensure that measures are taken to correct these problems wherever they exist.

The operation of power plants can cause thermal pollution of lakes and streams unless appropriate precautions are taken. These problems should be anticipated, and every effort should be made to keep abreast of the latest technologies for controlling, dissipating, and utilizing waste heat.

There are numerous methods for controlling thermal pollution. Once-through cooling is certainly the most economical method from the standpoint of plant operation, but very few water sources in the United States are large enough to handle significant quantities of heat without causing adverse environmental impacts. Impoundments such as cooling ponds, lakes, and reservoirs have been used to only a limited extent, primarily because land costs are often prohibitive and to be efficient a deep reservoir is required to take advantage of temperature stratifications. The addition of a spray system to an impoundment can increase the efficiency of heat dissipation, but this entails additional pumping costs and also increases water loss. A spray system does have the advantage of adding oxygen to the water that then could be returned to streams without causing oxygen depletion. Cooling towers, both wet and dry and natural and mechanical draft, are becoming more popular within the United States despite their higher cost. However, several problems exist that still have not been technologically or economically resolved, including wood deterioration, biological fouling, formation of deposits, corrosion and scaling, disposal or stack cleaning wastes, and water draft and fogging from the water vapor carried out of the top of the tower that condenses on contact with the air. Research is needed to determine which of these systems is best suited for use in DoD activities that generate thermal pollution.

Unique applications for beneficially utilizing waste heat (as part of DoD's "total energy" concept) are currently being investigated. They include:

- Development of satellite industrial and residential areas around waste heat generating plants that could use the heat to make low cost energy or to heat homes.
- Combining nuclear plants with desalting plants making use of the waste heat from the nuclear plant as energy input to the desalting plant.
- Utilization of warm cooling water for irrigation projects to stimulate plant growth and to protect fruit from killing frosts.

The Navy's ship maintenance facilities need to be evaluated in detail. The chemicals used for cleaning ships, their disposal, and the painting of ships can cause environmental impacts unless these activities are adequately monitored and controlled to prevent release of harmful materials. Current efforts to develop cleaning chemicals and paints that are less damaging to the environment need to be supplemented and extended.

The maintenance and operation of air bases can cause environmental impacts on water quality. The cleaning of airplanes and the storm runoff from runways can introduce contaminants into the sanitary waste treatment system that are difficult to process. Efforts are needed to determine ways of modifying these activities or to construct facilities to treat these wastes before they are introduced into the waste treatment system. Special emphasis is needed to develop biodegradable detergents for all types of maintenance activities.

C. Hazardous or Potentially Hazardous Military Operations

DoD recognizes a number of hazardous or potentially hazardous military operations, and is currently attempting to resolve the problems.

Deep water dumping of obsolete munitions and chemical and biological agents has recently been suspended pending a study of alternative methods of disposal. As disposal of toxic substances directly into surface waters and the ocean is curbed, the land may become the last receptacle for disposal of such wastes. However, the Toxic Waste Disposal Control Act (Reference 3, p. 118) calls for a nationwide program to regulate both land and underground disposal of wastes hazardous to human health. Therefore, DoD must keep abreast of all regulations and procedures stemming from this program. Alternative disposal methods that should be investigated include the following: (1) noncorrosive, indestructible containers that could be buried in the ground or dumped in the ocean, (2) deep well injection into unused confined strata that are below all potential ground water sources (this method should be used only as a last resort and then with extreme caution so as not to contaminate ground water supplies and induce earthquakes), (3) chemical or electrochemical methods of neutralizing toxic materials, and (4) anaerobic bacteriological treatment or other biodegradation techniques. Particularly needed is the development of accurate monitoring devices to determine when chemical and biological agents have been neutralized to the point of being nontoxic.

DoD is still using many herbicides and pesticides, although some, such as herbicide Orange and pesticide DDT, has been either totally banned or limited to very specific uses. The technology of biological control of insects and pests (chemosterilants, insect pathogens, and disruption of insect physiological processes) is still in its infancy and is an area of great potential for DoD research.

An inventory of photographic processing and electroplating waste disposal methods should be taken throughout DoD to ensure that they are ecologically sound. Research is needed to determine improved methods for reprocessing photographic processing wastes for reuse.

The operation of training areas has the potential for producing environmental impacts on water quality. The short term concentration of troops intensively using an area may lead to the following problems unless adequate precautions are taken:

- Open pit latrines, unless adequately located and operated, can lead to the eventual pollution of ground water supplies.
- Intensive use of tracked vehicles and the concentration of non-tracked vehicles may temporarily destroy ground cover, thus paving the way for soil erosion of the land and sediment problems in streams.
- Weapons firing often results in brush fires, which again destroys ground cover, leading to soil erosion and sedimentation problems.
- Field maintenance of military vehicles often entails disposal of waste engine lubricants that can contaminate ground water supplies.
- Training with large engineer construction equipment can create large barren areas potentially susceptible to soil erosion.
- Disposal of waste field packaging (e.g., C-ration cans) and garbage can eventually result in water pollution problems.
- Vehicle stream fording operations should be coordinated so as not to disturb the natural regime of the stream, thus leading to potential aggradation or degradation problems.

A thorough assessment is needed of the potential pollution hazards of training operations. Every effort should be made to dispose of wastes by ecologically sound methods. Reclamation and revegetation programs should be established to rehabilitate ground cover destroyed by fires or by military vehicles or activities. Field operations should be scheduled so that the field areas can recover their natural vegetation largely by natural processes (supplemented by reclamation efforts) and so that sanitary waste quantities do not exceed the assimilative capacity of ground and surface waters. Exercise Exotic Dancer V[5] is an example in which some of the above concerns were considered in the planning of a training exercise. However, this exercise was scheduled during the worst fire danger period in the Croatan National Forest. Efforts should be made in the future to avoid scheduling such massive training operations during critical fire hazard periods or other times when adverse environmental consequences may result.

Military excavation operations have the same potential for producing environmental impacts as do civilian operations. The potential for hazardous materials being introduced into ground and surface waters is ever present. Unless depleted excavations are revegetated, the potential for soil erosion and sedimentation also exists. The introduction of excess nutrients into streams can lead to algae problems, which eventually could affect fish in the streams.

The practice of using obsolete, deactivated ship hulls for target practice probably has minimal environmental impact provided the hulls are properly cleaned of all contaminants before being sunk. Caution should be used in selecting the sites for sinking these hulls so that they will not interfere with the development of potential resources on the sea bed that might possibly be exploited in the future. It must be recognized that this practice makes the recovery of perhaps scarce raw materials in the hull irretrievable.

Special attention is required to DoD's activities in cold regions (e.g., Alaska), where the ecology is extremely fragile and takes a long time to recover once it has been disturbed. Canada has claimed a 100-mile marine pollution control zone from its shores (above 60°N latitude), arguing that the Arctic region is in need of special protection from oil and other spills because the intense cold causes pollutants to persist for a long time (Reference 3, p. 88). The operation of tracked vehicles rapidly destroys the tundra which requires years to regenerate, if regeneration is possible at all. The development of more effective ways of insulating structures, roads, and pipelines so as not to melt the permafrost (thus causing stability problems) is an area that has been examined extensively but that needs more attention. Research is required concerning the full range of potential impact resulting from DoD activities in these areas, as is development of methods to either modify the activities or minimize their impact on the environment.

D. Equipment Use

Probably the most significant environmental impact in the use of equipment in the operation of Navy and, to a lesser extent, Army vessels, concerns the disposal of sanitary and oily wastes resulting from ballasting, tank cleaning, and refueling at sea. DoD is striving to comply with the President's "no intentional discharge" guidelines.

In the past, ships were not equipped with treatment systems, and they dumped untreated sanitary wastes into the surrounding waters. However, the Federal Water Pollution Control Act of 1970 requires EPA to establish federal standards for ship waste discharges to coastal waters. Two solutions are possible: either (1) temporarily retain the wastes on board and discharge them at a shore facility or in unrestricted waters (CHT--collection, holding, and transfer) or (2) treat the wastes on board according to acceptable standards and then discharge them into the water (MSD--marine sanitation device). The CHT method is currently being used on existing ships as they are being overhauled. The holding capacity of 12 hours, the current design criterion, might be adequate in many cases. The MSD system is being installed on some new ships, although the emphasis is toward the CHT method since it appears to be more economical. Special attention must be directed to ensuring that adequate shore facilities are available at all ports where ships operate and that shore discharges are coordinated so as not to overload the land based sanitary treatment facilities. At an early date, a comprehensive survey should be made of all ports from which DoD vessels operate to determine: (1) the local water pollution standards that must be met; (2) the potential for joint use of local treatment facilities; and (3) capacities, locations, and operations of local facilities. Once the above is accomplished, it should be possible for DoD to develop uniform waste discharge standards for its vessels that will assist ship commanders in meeting the local water pollution regulations. In developing these standards, DoD should give careful consideration to the recent 12-mile territorial limit for enforcement of the Federal Water Pollution Control Act and also to proposals to extend the limit for discharges to 200 miles. These limits could significantly affect the economics of waste disposal schemes that are currently being investigated.

In the past, DoD vessels discharged oil-water mixtures overboard during bilge pumping, tank cleaning, and ballast operations. Also, because of procedures used in refueling at sea, raw fuel was often accidentally discharged, which was wasteful and leads to environmental impacts. The Oil Pollution Control Act of 1961 and the 1970 Federal Water Pollution Control Act prohibit intentional discharge of oily wastes within 50 miles of shore, and it appears that soon all oily waste discharges will be prohibited. DoD is currently investigating the following methods for handling these problems:

- Holding the oily wastes for subsequent shore disposal and treatment
- Developing a series of filters and oil/water separators allowing disposal of the "clean" water and holding the concentrated oily wastes for subsequent shore disposal.
- Reducing the number of outlets from fuel tanks thus minimizing the accident potential.
- Installing backup emergency control systems to reduce accidental spills.

- Developing chemical barriers inside fuel tanks to avoid contact between residual oil and ballast water.

- Developing on-line monitoring equipment that will allow waste water discharge that meets acceptable quality standards.

- Developing more effective methods for containing and cleaning up oily wastes that are accidentally discharged. The National Oil and Hazardous Substances Pollution Contingency Plan, revised in August 1971, establishes procedures for coordinated federal action against spills.[1,6] The DoD needs to be informed concerning these procedures so as to modify its operations accordingly.

  Methods that DoD should investigate include monomolecular surface films; certain types of bacteria that feed on oil; corraling the oil with floating booms and then withdrawing it with a vacuum line; skimming devices; various chemicals to corral an oil spill, dispersing it into tiny drops for bacterial decomposition; and a machine developed in The Netherlands that sprays a mixture of treated sand and water over the oil, causing the oil to stick to the sand, which then sinks. Private companies also are developing methods for handling oil spills (see Reference 2, p. 18-8), including: (1) Ocean Science and Engineering, Inc., which is working on an aircraft deliverable system featuring collapsible, inflatable, rubber coated bladders for transporting oil from a distressed tanker; (2) Lockheed Missiles and Space Company, which is designing a device (Clean Sweep) that uses rotating drums to pick up oil on both sides of a number of closely packed vertical discs half immersed in the sea; (3) Ocean Pollution Control, Inc., with its patented Sea Sweep, a skimming device that picks up and pumps the oil water mixture to gravity tanks for final separation; (4) Ocean Systems, Inc., which is developing a dynamic keel containment system for containing oil spills in four- to five-foot waves; and (5) Avco Systems Corporation, which developed a magnetic fluid that is soluble in oil but not water and disperses throughout an oil slick which is then picked up by a magnetic boom. All these systems have potential for DoD use and should be investigated further. However, chemical methods could produce serious adverse biological effects and great care must be used in their application.

Additional research efforts would appear to be appropriate in the following areas:

- Development of methods for economically reclaiming oily wastes for either reuse by DoD or resale outside DoD.

- Development of methods for economically removing the soluble fractions of oil, many of which are toxic (e.g., benzenes, naphthalenes, diphenyls, mercaptans, and tetrahydronaphthalenes).
- Development of new fuel oils that not only reduce the particulate matter and SO_2 emissions but also contain lesser concentrations of soluble materials.

Potential water quality environmental impacts resulting from aircraft operations can be caused by an airplane accident or the practice of dumping fuel. The pollution potential of either situation depends strongly on the geographical location where they might occur. If they occur over the ocean, the impact may be small, because jet fuel is less dense than water and thus will not sink or mix with the water. Also, jet fuel is volatile and readily evaporates in the open air. Consequently, unless the dumping occurs in a populated area where the fuel could directly enter a water supply system or affect recreation activities, the impacts will probably be minimal. Every effort should be made to ensure that these activities will not occur over populated areas.

E. Research and Development, Classified Activities, and Policy Issues

Numerous DoD research and development activities are classified, and thus information regarding them is not generally available to the public. However, according to DoD Directive 6050.1, 9 August 1971, Section VI, classified activities are subject to requirements of NEPA. This means that environmental impact statements (EIS) must be filed, but these are handled in a classified manner. Wherever feasible, EIS should be organized so that the classified portions can be included as annexes to allow the unclassified portions to be made available to the public. Clearly, this places a great responsibility on DoD to recognize which of its R&D classified activities have the potential of being "major actions and significantly affecting the quality of the human environment," thus requiring the preparation and filing of an EIS.

It is acknowledged that many potential impacts (both short and long term) from R&D testing activities are unknown and therefore difficult to predict. It is also becoming apparent that to wait for long term problems to surface may be too late to take effective action since by then the problem will have become much more difficult, and alternative solutions could be more limited and more costly.

In developing its operational procedures and safeguards for testing R&D work, DoD makes every attempt to avoid environmental damaging impacts.[1] But these operational procedures and safeguards are necessarily based on DoD's perceptions of the potential environmental impacts and on its estimates of the probability of occurrence of accidents. It is essential that adequate information be available to aid DoD in recognizing a potential impact so that it may incorporate adequate safeguards to prevent its R&D classified activities from resulting in unforeseen adverse environmental impacts.

High explosive and nuclear cratering experiments are examples of classified R&D activities. These experiments have the potential of affecting both ground and surface water. Ground water can be affected if the blasts disturb an aquifer, creating conditions that could allow contaminants to enter (e.g., radioactive chemicals). Surface water can be affected by rain washing radioactive dust particles from the land into streams and lakes. Both possibilities could endanger environmental quality, and every caution should be taken to ensure that problems of this nature are minimized. This will require an intensive and extensive monitoring program both before and after the test. Also, unless the blast craters are backfilled and revegetated they can lead to increased erosion.

Another example of a controversial classified R&D activity is Project SANGUINE. The major environmental concern has been the uncertainty of the effect of extra low frequency (ELF) radiation on both humans and wildlife.

But the installation of this system (and its prototype) can have serious consequences to the surrounding ecosystems. The laying of the underground antenna cable crisscrossing the forests and the crossing of streams can create erosion problems unless adequately handled. The low frequency signals may have an adverse effect on fish where the antenna cables cross streams.

With respect to policy issues, when DoD components are in the field they necessarily recognize the importance of efficient utilization of water; but in fixed military installations and in routine supporting activities, DoD's attitude toward water use is not likely to differ from those held by the rest of society. These attitudes have been that water is essentially a free commodity and available in unlimited quantities to be used at will. However, many parts of the country could be facing severe water supply problems.

Instead of looking for new water supplies to develop, which are becoming costlier and scarcer as the population grows, many economists and water resource planners are advocating education of the public to the true "social costs" of water, thus attempting to bring water rates in line with these social costs. Although only a partial solution, the hope is to make the public more concerned about utilizing water more efficiently. The concept of a flat water rate will require review in light of changing conditions, as will the subsidized water supply developments for various groups (such as agricultural interests). The social costs of water development include the array of environmental costs, the opportunities lost for investing money spent on water development that otherwise could have been spent on other problems, and the cost of treating the vast amounts of waste water that are generated.

DoD is in a unique position to take the lead in more efficient utilization of water. Because of its structure, DoD can influence attitudes of the personnel directly under its command toward water use and can also persuade supporting activities to adopt the same attitudes.

Water could be used more efficiently in many areas of DoD activities, including those discussed briefly below.

- Certain traditional and routine activities could be evaluated from an environmental point of view, such as a study based on maintenance characteristics of military vehicles to determine optimum vehicle washing times with a view toward conserving water.
- Water that is used for washing vehicles and other similar routine operations, with a minimal amount of treatment, can be recycled for future maintenance operations, thus conserving considerable amounts of water.
- Sewage plant effluent, instead of being returned to rivers, could be used for a multitude of purposes such as lawn sprinkling washing of vehicles, coolant for industrial operations, irrigation of certain crops, and even for drinking purposes if the social stigma against this can be overcome (provided it is treated to Public Health Department Standards).
- Storm runoff, instead of being disposed of, could be stored in small underground reservoirs for certain future uses during critical water shortage periods.
- Shower heads, toilets, and other water consuming facilities can be modified to make them more efficient with respect to water use.
- Methods could be developed for providing field water supply from waste water reuse. The current work on foam separation, hydrocyclone solids separation, disinfectants, and carbon absorption should be continued and expanded.

It is suggested that DoD expand research in all areas that might be targets for more efficient use of water and for potential reuse by recycling. It must be emphasized that more "new" water can be provided by controlling pollution than by any other means of water supply development. Pollution control also has the advantage of permitting the use of an already available distribution system--the country's waterways--to deliver water of satisfactory quality to points where it is needed.

Another policy that needs investigation concerns the environmental impacts from concentration of DoD personnel activities. In making decisions on increases in personnel at various bases, closing of bases, scheduling of intensified training activities, and so forth, efforts should be made to ensure that the environmental capability of the local area and the local civilian community will not be overtaxed. It may be possible to shift personnel and activities and to reschcdule training activities to decrease the environmental impact of DoD operations without affecting the overall effectiveness of various DoD activities.

As noted earlier in this section, efforts are needed to establish a comprehensive data collection and monitoring program of all DoD activities as they affect water quality. The Navy's Port Hueneme research project[7] is an excellent example of what is required from DoD. Research is also needed to determine what monitoring equipment is best suited for DoD needs, with emphasis on automatic monitoring and control equipment, especially in operations dealing with hazardous materials. Work is also needed to determine how the data collected are to be used for setting and implementing DoD pollution control policies. The collection of data that are required to compute EPA's prevalence/duration/intensity index (Reference 3, p. 11) is another important need. This index allows any water body to be described in terms of the prevalence, duration, and intensity of its water pollution corrected for natural background pollutant levels. The index is based on the extent that water quality deviates from federal-state water quality standards. Currently, the index does not identify the type of pollutant responsible for the pollution (e.g., BOD, suspended solids, nutrients), but EPA plans to add this information soon. Therefore, identification of pollutant types should be considered in selecting monitoring equipment.

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CHAPTER SIX--WATER QUALITY
II--DEEP WELL INJECTION, REVERSE OSMOSIS, AND MONITORING OF TRACE ORGANICS

II DEEP WELL INJECTION, REVERSE OSMOSIS, AND MONITORING OF TRACE ORGANICS

A. Statement of the Problem

Because of its manifold activities and size, the DoD and its supporting industries are important consumers of the nation's water. Water "consumption" and water "pollution" clearly are interrelated; except for the fraction of water that is vaporized and turned into atmospheric moisture, the quality of water used for industrial or other purposes is often lessened and returned into the streams, lakes, or oceans to be purified by natural processes. When the natural capacity of streams to purify themselves is exceeded, pollution becomes serious and artificial water purification becomes necessary. A detailed assessment of the extent to which DoD activities contribute to the deterioration of ground water quality and what can be done about it is required.

B. State of the Art

The technology of water reclamation is relatively well developed. It is possible to restore water to fresh water quality through a series of steps, generally referred to as primary, secondary, and tertiary treatment. Many present water pollution problems occur not because of inability to handle them but because available technology has not been applied to treatment of discharges.

The most serious general problem that conventional water treatment methods cannot handle is an increase of salinity or total dissolved solids. Also, specific, localized problems, such as oil spills or the dumping of certain toxic materials, require specialized treatments.

C. Implications for DoD

The majority of water pollution problems arising in connection with the operations of the DoD are amenable to conventional treatment, but many are not because of DoD operational, geographical, or physical constraints. Also, DoD operations often require the disposal of expecially hazardous materials, where disposal methods require special attention to guard against adverse environmental effects. The DoD is in a unique position to develop and apply advanced wastewater treatments to more intractable problems because of the high degree of control it exercises over its operations.

D. Recommendations for Further Studies

An assessment of the extent and degree of water pollution resulting from DoD operations is needed as a basis for further consideration. The assessment should be followed by an evaluation of situations likely to require specialized treatment. A preliminary list of topics should include the following areas, which then are described in some detail.

- Disposal of wastes--deep well injection
- The application of reverse osmosis to waste disposal problems
- Control and monitoring--trace amounts of organics.

1. Disposal of Liquid Wastes--Deep Well Injection

The nature of the water cycle is such that materials are carried through geological processes to the oceans, which constitute the ultimate repository of all inert and water soluble material. Man can affect only the rates of these processes, not their ultimate outcome. When human activities greatly accelerate these rates, the process is out of balance and the undesirable effect known as pollution becomes apparent. In this context, water pollution control is an effort to slow down the transport by the streams and rivers to the ocean of solubles resulting from human activities; this is done by separating the dissolved materials from the carrier-water and disposing of them separately. Frequently, one type of pollution is only traded for another: aeration of a lagoon may result in air pollution; settling and sedimentation produce solid wastes. In the case of reverse osmosis discussed below, a concentrated brine stream results in addition to the reusable product stream.

Ultimate disposal of concentrated waste streams can take place only by three mechanisms: (1) they can be transported to the ocean in pipelines or especially designated surface channels; (2) they can be evaporated either by the use of evaporation ponds (solar evaporation) or by application of heat, thus producing a solid waste product; or (3) they can be returned to the earth by deep well injection.

Each approach offers certain advantages and disadvantages. Transporting of waste streams does not achieve the objective of slowing down the collection of materials in the ocean, although it localizes the objectionable process. Evaporation requires either a favorable climate and large areas for ponding (which are not likely to be available in an urban, industrialized area) or the use of fuel for evaporation to dryness. Deep well injection could provide a partial answer but requires considerable additional research.

The petroleum industry has been using deep well injection of oil field brines quite successfully for many years; however, this constitutes a somewhat unique geological situation, since the very existence of an oil field indicates a geological structure capable of storing large quantities in a liquid phase. Disposal of hard-to-handle industrial wastes by deep well injection has become more common during the last two decades. In general, the technique consists of injecting the waste material into a sufficiently porous rock structure, located well below fresh water aquifers and isolated from them by an impermeable sedimentary layer. Considerable pressures are used (usually from 200 to 1000 psi), and care must be taken to maintain an impermeable well casing reaching below the level of ground water aquifers.

In addition to the obvious factors of a suitable geology, of waste compatible with the dispersal stratum to avoid plugging by either solids or by any gases formed by interaction of the waste and the rock, and of the mechanics of the injection process itself (which frequently entails the handling of toxic and corrosive materials), important questions remain to be answered. One group of problems relates to the long range (50 to 500 years?) aspects of deep well disposal--to the long term fate of the injected fluids and to the eventual dispersion into distant areas, creating both legal and health problems. Another area of uncertainty is the overall effect of water injection on the geological stability of large areas, as demonstrated by the occurrence of numerous earthquakes in the Denver areas, which were traced back to an underground injection system at the Rocky Mountain Arsenal. Adequate monitoring of the effect of injections constitutes another area of needed investigation to obtain the essential information required for the assessment task.

2. The Application of Reverse Osmosis to Waste Disposal Problems

Conventional wastewater treatment is designed to remove suspended materials by sedimentation, coagulation, or filtration (primary treatment) and to reduce the level of dissolved organic material by oxidation (aeration) or by biological decomposition (secondary treatment). The concentration of organics can be lowered further by a third step (tertiary treatment), which usually consists of treatment with activated charcoal.

The quality of the effluent from tertiary treatment facilities frequently equals or exceeds drinking water standards with respect to clarity, color, odor, and bacterial count. However, none of these treatments reduces the amount of dissolved inorganic solids, which manifest themselves as hardness (primarily calcium and magnesium) or salinity (usually sodium chloride or sulfate). In hard water areas, primarily the Western United States, the mineral content of fresh water tends to be close to the upper acceptable regulatory limit of 500 ppm. Because of evaporation or addition of soluble salts, the dissolved solids content increases 200 to 300 ppm during each cycle. For example, reclaimed water in the Los Angeles area cannot be reused, because its total dissolved solids (TDS) content ranges upward of 700 ppm. Similar situations prevail in other semiarid areas, where the treated wastewater is sometimes so saturated with dissolved solids that it cannot be discharged into nearby rivers, even though it is otherwise "pure."

Of the several technologies available to remove dissolved inorganics, such as distillation, ion exchange, and reverse osmosis, the latter has the greatest potential in wastewater treatment. The process is relatively simple: the saline solution is pumped under considerable pressure (typically 400-800 psi) past a "semipermeable membrane." This membrane passes water but rejects dissolved materials. Thus, two streams result--a product stream, typically 80 to 90 percent of the feed, containing from 1 to 10 percent of the original TDS (depending on the type of membrane used), and a concentrated waste stream (10 to 20 percent of the feed), containing the bulk of the minerals.

The major advantages of reverse osmosis in wastewater treatment are: (1) it produces a high quality product; (2) it removes essentially all dissolved or suspended materials, whether they are minerals, color bodies, or bacteria; and (3) it can handle wastewater that had only a primary treatment (sedimentation).[1] The principal disadvantages

[1] J. M. Smith et al., Renovation of Municipal Waste Water by Reverse Osmosis, EPA-WQO Report No. 17040 (May 1970).

are: (1) the cost is estimated to be of the order of \$1 per 1000 gal (\$325 per acre-foot) and (2) the application of reverse osmosis to wastewater treatment is in an experimental stage, and many important operating parameters are unknown. Considerable research and development work needs to be done for the technique to become generally applicable. Demonstration of the potentials by DoD to meet requirements at certain of its installations could benefit the public generally through advancement of this promising technology.

3. Control and Monitoring of Trace Amounts of Organics

Since all living organisms depend on the presence of oxygen in some form, the presence of dissolved oxygen in water indicates its ability to support life. Oxygen is only sparingly soluble in water, and many processes compete for it. The self-purification of streaming waters is essentially an oxidation process, resulting in a removal of organics by conversion to carbon dioxide and water by means of bacterial degradation. The bacteria, in turn, use oxygen, thus acting as catalysts in a low temperature oxidation of organics. The amount of oxygen required to completely oxidize all biodegradable material is called "biological oxygen demand" (BOD) and constitutes a measure of organic contamination of a stream. A stream containing an excessive amount of organic pollution will not support life even though the organics are not in themselves toxic, simply because of the oxygen depletion resulting from the gradual oxidation of such organic matter. Thus the discharge of "unstable" wastes having a high biological oxygen demand must be avoided.

Determination of the oxygen demand by simulating natural processes in the laboratory is a tedious procedure, requiring some 20 days. A more practical test is the "5-day BOD," which accounts for about 85 percent of the final demand. Clearly, that is still too long for control purposes. A so-called "chemical oxygen demand" (COD) test has been developed, wherein the oxidation is performed by refluxing the sample with a chemical oxidizer (usually potassium dichromate). This test can be made in a few hours; the results are not identical with a BOD test, since some materials not attacked by bacteria are also oxidized by the dichromate, but it constitutes a useful estimation of oxidizable materials.

There are many situations where a rapid, preferably continuous method for measuring total organics would be highly desirable; for example, in disposing of ballast water from the hold of tankers, the organic content of the water fraction of an oil-water separator needs to be known before it can be discharged. Continuous monitoring of treated waste would allow holding lagoons to be eliminated, and the remote monitoring of streams and rivers would permit much better control of effluents. Although instrumentation has recently become available that is capable of determining a COD equivalent in a matter of a few minutes, the instrumentation is complex, sensitive to ambient conditions, and requires frequent standardization in the laboratory. Thus, a field instrument capable of remote monitoring of the organic or total carbon content of water samples in the range of 0-200 mg/1 of COD should be developed.

CHAPTER SIX--WATER QUALITY
III--AERIAL SURVEILLANCE SPILL PREVENTION SYSTEM

III AERIAL SURVEILLANCE SPILL PREVENTION SYSTEM

A. Statement of the Problem

Spills of crude oil, refined products, and hazardous polluting substances in inland and coastal waters come from many sources and pose a constant threat to beneficial use of these waters and adjacent shorelines. A primary source of these spills are onshore facilities adjacent to inland and coastal waterways that handle volumes of oil and hazardous polluting substances. Refining, processing, transferring, storing, and transporting operations all possess potentials for spills escaping into adjacent waterways. In 1968, 285 incidents of oil spills from onshore facilities were reported to the Coast Guard.[1]

The other major source of spills is vessel operations. Bilging, overfilling, willful dumping, transferring operations, and accidents also have the potential for introducing hazardous materials into coastal waters. In 1968, 348 incidents were reported to the Coast Guard (50 of which were military) of oil spills resulting from vessel operations.[2] In 1971 the following incidents of polluting spills were reported to the Coast Guard:[2] 2086 incidents from vessels, 1932 incidents from transportation related facilities, 2022 incidents from nontransportation related facilties, and 2456 incidents from miscellaneous and unknown sources. The vast difference in the number of spills reported between 1968 and 1971 is because

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[1] Environmental Quality, Third Annual Report of the Council on Environmental Quality, p. 120 (August 1972).

[2] Prevention of Pollution by Oil and Hazardous Materials in Marine Operations, Commander A. G. Stirling, in Proceedings, Joint Conference on Prevention and Control of Oil Spills, American Petroleum Institute (December 1969).

of new reporting requirements. The above combined 8496 incidents resulted in 9 million gallons of hazardous material being dumped into U.S. waters.

Past spills from onshore facilities and vessel operations have seriously affected beneficial uses of the Nation's waterways and coastal waters and in many instances have caused considerable known damage. In addition, the insidious accumulation of small spills of deleterious substances and drainage of these materials from waste lagoons, tank farms, and slag heaps of industrial waste materials need to be identified so that corrective measures can be taken.

Much research has been or is currently being done on developing and perfecting methods for cleaning up oil spills once they occur and once they are identified. Until recently, little emphasis has been given to methods for identifying hard-to-detect spills or to the use of aerial surveillance as an "early warning system" which would make it possible to identify potential hazardous situations that could lead to major spill problems. It should be noted that any such effective early warning system must combine ground surveys and measurement techniques with the emerging science of remote sensing.

B. State of the Art

Present remote sensing methods are based on the electromagnetic energy either reflected or emitted by the feature being observed. The electromagnetic properties of various features are wavelength-dependent, that is, spectrally distributed, and in principle this dependence is uniquely related to the chemical species and the physical state of the material.

Current passive methods using naturally occurring radiation include panchromatic film, color film, ultraviolet film, multispectral methods, infrared radiometers, infrared line scanners, microwave radiometers, thermal scanning devices, and the Fraunhofer Line Discriminator used to sense solar stimulated fluorescence. Active methods, in which the source of radiation is an integral part of the instrumentation, include both radar and lasers used in a radar like configuration.

Swaby and Forziati[3] summarize the state of the art of aerial surveillance as follows:

> All methods investigated so far have the ability to detect the presence of a surface film. However, the potential for positive identification of the film substance appears to be offered by multispectral methods only. Unfortuantely, the methods (UV through IR) by which spectral signatures are detectable become inoperable at night and/or in bad weather. On the other hand, microwave methods possessing all weather capability do not allow spectral differentiation. It may be that other recognition techniques are possible, but if so they have yet to be worked out. A more complete picture of remote sensing of oil spills will emerge after active and fluorescence detection methods have been fully investigated. These sensors will most likely have the capability of detecting and monitoring surface films but not of identifying the contents of the films. Nevertheless, we will have a choice of sensors useful under a variety of situations for detecting films with identification reserved for the laboratory.

C. Present Activities and Organizations

The U.S. Coast Guard, U.S. Geological Survey, and the EPA are the primary federal agencies that are currently investigating the use of aerial surveillance techniques for identifying spills of hazardous materials into U.S. waters.

The U.S. Coast Guard Office of Research and Development has either conducted or funded several aerial surveillance experiments. One

[3] L. G. Swaby and A. F. Forziati, "Remote Sensing of Oil Slicks," in Proceedings, Joint Conference on Prevention and Control of Oil Spills, American Petroleum Institute (December 1969).

experiment, conducted in the Gulf of Mexico, was concerned with the detection and quantification of oily discharges from vessels under way.[4] This experiment used black and white, color visible, color infrared, multispectral, and ultraviolet film and passive microwave radiometers to obtain data on five oil types at three ship speeds over a wide range of surface and atmospheric conditions. Another experiment, conducted off the Southern California Coast in late 1970, consisted of a series of controlled oil spills in which 330 gallons of four different types of oil were used. The objectives of this experiment were: (1) to obtain multispectral signature data of oil spills and to determine the capability of remote sensing techniques (including radar and passive microwave techniques) for surveillance and detection of slicks and (2) to determine from remote sensor and surface vessel observation the spreading rate and extent of the oil slicks in the ocean. The Naval Research Laboratory participated in two of the four controlled oil spill tests in this latter experiment.

EPA, in conjunction with the University of Michigan and North American Rockwell,[3] conducted tests of the Santa Barbara oil spill using panchromatic color infrared and ultraviolet photographs, multispectral methods and microwave radiometers to detect the presence of a surface film.

The USGS is currently developing the Fraunhofer Line Discriminator[3] which senses solar stimulated fluorescence. This device takes advantage of the fact that certain spectral lines are partially absorbed in the outer portions of the sun and appear at low intensities at the earth. These regions of low intensity allow detection of fluorescence even in the background of high overall solar intensity. Additional descriptions

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[4]C. E. Catoe and F. L. Orthlieb, "Remote Sensing of Oil Spills," in Proceedings of Joint Conference on Prevention and Control of Oil Spills, API, EPA, and U.S. Coast Guard (June 1971).

of current research on aerial surveillance methods are given in Table III-1.[5]

D. Implications for DoD

The recent federal, state, and local legislation, such as the Toxic Waste Disposal Control Act, the Federal Water Pollution Control Act of 1970, and The National Oil and Hazardous Substances Pollution Contingency Plan, all require that DoD activities meet certain water quality standards. To prove compliance with these standards will require monitoring systems. Aerial surveillance, in many instances, can be much more efficient than ground monitoring. Since DoD has developed much of the current aerial surveillance techniques for military operations and since DoD has aerial surveillance equipment, airplanes, and trained personnel, it would be in a favored position to transfer this technology to the monitoring of water pollution resulting from DoD operations. This effort could be of great assistance not only to DoD but also to civilian agencies concerned with water quality.

E. Recommendations for Further Studies

Application of the existing capabilities in remote spectral sensing to practical problems such as water quality surveillance has been relatively slow. A number of instrumentation developmental problems contribute to this situation, which is compounded by gaps in knowledge about the characteristics of features of water resources that are essential for interpretation of data obtained by remote spectral-sensing devices. Many demonstration tests have been conducted, but few practical, routine applications have resulted. Even attempts to identify user applications

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[5] Environmental Research Catalog, U.S. Environmental Protection Agency, Office of Research and Monitoring, Research Information Division (January 1972).

Table III-1

SELECTED CURRENT RESEARCH PROJECTS ON AERIAL SURVEILLANCE METHODS

Title	Performing Organization	Supporting Agency	Description
Investigation of Surface Films-Chesapeake Bay Entrance	Virginia Institute of Marine Science	U.S. Environmental Protection Agency	This study concerns determination of transport and fate of spilled oil in marine and estuarine waters. Included in the primary tasks are to: (1) Document compositional changes in oils spilled in the open ocean in Chesapeake Bay by gas chromatography, infrared spectrophotometry, column chromatography, and other techniques for oil analysis; water and oil samples will be analyzed to investigate losses of volatile and water soluble components of the oils; and (2) determine the effect of weather and water currents on the movement, spreading, evaporation, and diffusion of these fuel oils in the open ocean and Chesapeake Bay.
Development of Remote-Sensing Techniques to Determine Water Quality	NASA	NASA	Remote-sensing techniques that can be used to study the productivity, toxicity, and turbidity of water bodies will be developed, providing a data base from which to evaluate local and global effects on marine ecology from man-made and natural pollutants. Applications will include rapid determination of photosynthesis-induced productivity over large regions of the oceans; surveys of water quality following pollution abatement action; determination of presence and extent of a surface film as a toxic agent and barrier to oxygen transpiration; and delineation of tidal intrusions, currents, and water body boundaries. Airborne measurements will be performed to evaluate instrumentation such as a recently developed differential radiometer system (DRS) for operational use in determining chlorophyll, turbidity, and surface films through unique reflectance or polarization characteristics.
Ultraviolet Studies (Solar-Stimulated Fluorescence)	U.S. Department of the Interior	U.S. Department of the Interior--Geological Survey	Instruments and techniques are sought for remotely detecting substances that fluoresce when irradiated by sunlight. A prototype Fraunhofer Line Discriminator (FLD) operating at the amber sodium-D2 line (5890 angstroms) has been converted to operate at the blue hydrogen-F line (4861 Å). Conversion to the deep red hydrogen-C line (6563 Å) is commencing. The sodium-D2 FLD proved useful as an airborne or shipboard fluorometer over water, measuring substances that fluoresce amber, such as rhodamine dyes. Rhodamine WT was monitored in concentrations below 55 ppb in clear river water, moderately turbid marine coastal water, and highly turbid estuaries. Ultimate objectives are to develop capability to monitor pulp and papermill effluents by the fluorescence of lignin sulfonates and the distribution of phytoplankton by chlorophyll fluorescence and to monitor other pollutants such as oil spills, detergents, or chemical wastes.

Table III-1 (Continued)

Title	Performing Organization	Supporting Agency	Description
Ultraviolet Studies (Continued)			Tasks include development and testing of airborne instruments and survey techniques and of data-compilation procedures to permit either qualitative or quantitative applications of remote fluorescence analysis.
Feasibility Study of Water Resource Pollutant Identification by Digital Computer Analysis of Remote Infrared Sensor Spectral Intensities	Clemson University School of Engineering	South Carolina State Government	This study will determine the effectiveness of a remote, multiband, solid-state, infrared sensing system as an aid in water resources management, including detection of industrial contaminants and thermal pollution surveys and surveillance in the Piedmont area of South Carolina. The research tasks include: (1) characterization of a representative sample of industrial pollutants in terms of their emission spectral signatures; (2) definition of a scanning infrared sensor system with appropriate optical and electronic instrumentation; (3) development of suitable algorithms for computer identification of pollutants, using information obtained from the sensor array; and (4) laboratory and field testing a complete system, including the correlation of the results with data obtained at the sites. It is proposed that pollution events can be identified and monitored on-line in an essentially real-time operation. The final configuration of the system will use a small general purpose integrated circuit digital computer, plus the infrared sensing system, in an overall form that would afford federal, state, and private agencies and organizations with an on-line means for monitoring municipal and industrial effluents.
Application of Remote Sensing to the Determination of Water Quality	University of Wisconsin Institute of Environmental Studies	NASA	This research is directed to establishment of correlations between aerial remote sensing responses and water pollution parameters. Once established, these correlations will be a valuable tool in both the enforcement of water pollution legislation and the overall planning of a given watershed. The spectral reflectance and radiant emission properties, as measured in the laboratory using Gamma Scientific and Isco Spectro-radiometers, will be studied for samples containing known chemical, physical, and biological characteristics. The reflectance and emission properties will be correlated with specific water pollutants, and the relative magnitude of these radiant emission properties of water will be conducted in situ through radiometric measurements. The correlation between these two properties in specific water pollutants and secondary pollutional indicators will be established. From laboratory and field measurements, aerial remote sensing responses will be interpreted and appropriate wavelengths and/or combinations will be established for specific pollutional parameters. In coordination with Wisconsin state agencies, spectral bands cill be prescribed and data handling and analysis techniques developed so that the findings can be used as a practical tool for water pollution control.

Table III-1 (Concluded)

Title	Performing Organization	Supporting Agency	Description
Technological Assessment of Remote Sensing	University of Michigan	U.S. Department of the Interior	The investigation is designed to critically review, examine, and analyze the applicability of airborne and other remote sensing instrumentation and techniques for the detection and characterization of water pollutants in the following general categories: (1) substances floating on the water, (2) substances suspended in the water, (3) substances dissolved in the water, and (4) material on the bottom of ponds, lakes, and estuaries. Specifically, the study will define the capabilities of (1) operational and near operational systems and (2) systems currently in the research and development stage to remotely characterize effluents and receiving waters in terms of water quality parameters. It will attempt to identify areas of research and define concepts that could lead to the development of new remote sensing systems capable of providing the physical, chemical, and biological measurements of interest in water quality management.
Application of Remote Sensing to the Determination of Mixing Zone for Waste Effluents Discharged into Streams or Rivers	University of Wisconsin	NASA	The basic objective is to develop a relationship for the extent of the mixing zone in terms of the characteristics of the outfall, effluent, and water body. Using this definition of a mixing zone, government agencies could establish a reasonable sampling and regulation program for waste effluent discharges. Through an extensive literature search, a working hypothesis for the extent of the mixing zone as a function of outfall, effluent, and water body characteristics has been developed. The literature search will continue and be expanded to include additional laboratory and field studies. Using laboratory flumes and tanks to simulate idealized river and lake environments, rates of dilution or mixing of tracers will be measured. Mathematical models will be developed along the lines of classical jet and plume analysis, subject to the constraints of type and location of the outfall and the environment. Intensive aerial remote sensing and detailed ground measurements of waste effluent concentration distribution temperatures and velocities, will be undertaken. The observed and predicted mixing zones will be compared, using the functional relationship developed.
Application of Remote Sensing to Surface Parameters of Large Water Bodies	University of Wisconsin	NASA	This research centers around the detection and monitoring of oil and thermal pollution, as well as the determination of near-shore circulation patterns. An attempt is being made to find a remote sensor that will suitably detect an oil slick from an aircraft or satellite platform. Current research dictates that instruments operating in the UV or microwave portions of the spectrum will be useful. The spectral responses of oil samples in the visible spectrum will be determined with a spectrophotometer, revealing any possibility of using a particular film filter combination or showing a need for a UV scanner. The possibility of using an instrument operating in the microwave region will be determined from a literature search. Infrared radiometers will be used initially to monitor thermal plumes from nuclear power plant discharges, with infrared scanners used later. Seasonal changes in the thermal structure of the receiving water will be studied. Airborne infrared radiometry will be used to detect and monitor near-shore circulation patterns.

for the methods already developed have been only marginally successful, being either far too limited to be justifiable or far too broad to be practical.

Key research requirements at the present time are for both technological development and applications of remote sensing techniques to water quality management. Emphasis for future research should be directed to the application of remote sensing data to real problems, including the establishment and enforcement of rational water quality standards. A feasibility demonstration is required to assess the practicability of aerial surveys and associated data interpretation in covering the many, widely distributed spill threat sources and thus optimizing ground team inspection and enforcing actions.

A number of topics have potential applicability to DoD activities. Suggested for further study are to:

- Determine the feasibility of utilizing remote sensing aerial reconnaissance and photo or multispectral interpretation techniques to locate and identify potential spill sources along major waterways and in coastal areas.
- Determine which available sensors and interpretation techniques are best suited for the immediate implementation of a practical, effective, and economic aerial reconnaissance system for DoD activities.
- Investigate the state of the art of remote sensing to identify which sensors and techniques currently under development should be considered over the long range for improved versions of the reconnaissance system. The primary emphasis here should be on new sensors that will extend the capabilities and reduce the limitations of the first generation system.
- Determine the oil slick detection capability of various surveillance methods as a function of sea and coastal surface and weather conditions.
- Determine the feasibility of estimating oil film thickness from sensor characteristics.

- Investigate the potential for using surveillance techniques to positively identify the source of spilled pollutants. This activity must be coordinated with work being done on the development of various "tagging" techniques.

- Investigate the potential use of lasers in a radar-like configuration to detect pollutants at night.

- Develop a multispectral surveillance method that has an all-weather capability and is not limited to daytime operation during good weather conditions.

- Investigate the applicability of utilizing the following aerial surveillance system for accomplishing the tasks listed in Table III-2:

  - Prime vertical photography with sufficient overlap between adjacent frames to obtain stereo pairs for photogrammetric purposes.

  - IR radiometer with output recorded on a stripchart recorder.

  - Radiometer whose field of view is boresighted to correspond to the leading edge of the film imagery.

  - IR line scanner to map the location, extent, and motion of oil spills, as well as to provide data on valve positions, leaks, and tank levels when used in conjunction with conventional imagery.

The sensor configuration described above in theory could provide the information summarized in Table III-2 regarding the factors of interest in an oil and hazardous material spill prevention system. As can be seen from the table, most of the required data can be supplied by panchromatic and multispectral photography. Color photography and the IR sensors may add additional information; however, the need for the additional sensors must be weighed against the increased cost and complexity.

Table III-2

POTENTIAL APPLICATIONS OF REMOTE SENSING TECHNIQUES TO DOD ACTIVITIES

	Panchromatic Photography	Stereo Pair Photography	Multispectral Photography	Color Photography	IR Radiometer	IR Line Scanner
Bulk storage areas for oil and hazardous materials						
Number of tanks	X					
Structural condition of tanks--old, new, rusty		X		X		
Leaks or seepage around tank area	X		X	X		
Secondary control dikes--condition of dikes, volume behind dike, potential failure points, compacted or loose soil banks	X	X	X			
Drainage patterns--exit route for spilled material, drainage piping through dikes, valve condition (open or closed)	X				X	X
Piping in bulk storage area--above or below ground, condition of pipes, leaks, valving	X			X	X	X
Trash and debris behind dike	X					
Industrial waste storage lagoons						
Volume of lagoon, detention time inflow rate		X				
Source of waste product	X		X	X		
Dike conditions--compacted or loose soil, potential failure point, leaks	X		X	X	X	X
Effluent location--discharge point to river		X				
Open storage areas of solid wastes and raw products						
Volume and type of material	X	X	X	X		
Drainage pattern		X				
Observed drainage in waterway			X	X	X	X
Pipelines over or near waterways						
Condition of lines and holding structures over waterways	X			X		
Leaks	X		X	X		X
Railroads and tank cars located adjacent to waterways						
Spillage noted in transfer operations	X		X	X		X
Marine terminals						
Transfer operations	X		X	X		
Oil or pollutant materials in inner harbor or near piers			X		X	X
Refineries and industrial processing facilities						
Transfer operations	X		X	X		
Location of raw materials and types	X		X	X		
Drainage patterns		X				
Condition of storage tanks and pipelines	X		X	X		
Location of effluents and water condition near outfall	X		X	X	X	X

CHAPTER SIX--WATER QUALITY

IV--OIL SPILL CLEANUP TECHNIQUES

IV OIL SPILL CLEANUP TECHNIQUES

A. Statement of the Problem

Cleanup of oil spills from coastal waters entails (1) curtailment of the spilled oil, (2) collection and/or treatment of the oil leading to recovery or dispersal, and (3) restoration of beaches and coastal areas affected by oil washed onshore. Oil spill cleanup is influenced by the type of spill (sudden release of large amounts of oil from a ship or production facility versus relatively slow release of smaller quantities of oil over a prolonged period) and by the type of oil (crude oil versus refined products). The problem is to provide optimum and efficient means to remove and recover spilled oil with minimum additional disruption to the natural environment so as to facilitate rehabilitation and restoration of affected areas.

B. State of the Art

1. Containment

Oil spill containment at the surface of coastal waters is commonly attempted using mechanical floating booms.[1] The oil retention capacity of booms is influenced by:

- Wind and current, which can cause oil to "carry-over" or "run-under" the boom
- Wave characteristics and sea state
- Oil properties and spreading rate
- Boom characteristics, including freeboard-to-draft ratio, cross-sectional geometry, and longitudinal flexibility.

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The rate of spreading of different types of oil were reported[2] as shown below.

Material	Evaporation Rate	Toxicity	Rate of Spreading for 200-gallon Spill (ft/min)
Bunker C	Low	Least	0
Navy Special	Medium	Medium	2.7
JP-5 Distillate Fuel	High	Most	5.3

The risk of fire from oil spilled on water is commonly minimal because of loss of heat to the supporting water which inhibits burning. Thus, containment of spilled oil by mechanical means should not present an unusual hazard.

Oil spill containment equipment include mechanical booms, air barriers, and skimmers.[3]

- Mechanical booms can be used to control the movement of an oil spill and facilitate its recovery. Three types of mechanical booms are curtain, light fence, and heavy fence booms. Light fence booms are the most versatile.
- Air barriers use streams of air directed at the edges of a spill to contain its motion. These show promise for spill control at fixed installations.
- Skimmers are used in the recovery of contained oil from the surface. There are several types of skimmers, ranging from (1) separating skimmers that remove oil preferentially from water, (2) blotters that absorb oil, (3) suction skimmers that attempt to vacuum oil from the water, (4) separating columns that draw oil up to where it can be removed by suction, and (5) floating weir skimmers that take up water and oil for later separation.

The Maine Port Authority[3] has found it effective to use mechanical booms in connection with floating weir skimmers, and this technique was used successfully in the Gulf of Mexico oil spill following the Chevron Oil Company offshore platform fire. The principle used is to contain the spill and then "skim first and separate later." Emphasis on complete separation at the point of removal was found to create more problems than it solved, because separation slowed down the skimming process. Containment by mechanical booms is essential to this process because it is "far easier to skim effectively in a thick film of oil than a thin film." A classification of oil films is given in Table IV-1.

2. Collection/Treatment

Oil Spills may be collected or treated by a combination of mechanical and chemical means. A classification of chemical agents for treatment of oil spills is given in Table IV-2.[4] Chemical agents for treatment of oil spills are also grouped by their effect on oil.[5,6]

- Collecting agents, which can gell, sorb, congeal, herd, entrap, fix, or make the oil mass more rigid or viscous to facilitate surface removal.
- Sinking agents, which can physically sink oil below the water surface (in deep waters only).
- Dispersing agents, which emulsify, disperse, or solubilize oil into the water column or act to further the surface spreading of oil slicks to facilitate dispersal of oil into the water column.[7,8]

Dispersants are intended to promote thinning of oil and increase the rate of biodegradation. Originally they were applied in a fine spray in relatively undiluted form, followed by agitation to enhance the dispersal process. Specially designed vortex separation equipment was developed to aid the dispersal and recovery process.[9,10]

Table IV-1

CLASSIFICATION OF OIL FILMS
(Thickness Less than 0.001 Inch)

Standard Term	Gallons of Oil per Square Mile	Appearance
"Barely visible"	25	Barely visible under most favorable light conditions
"Silvery"	50	Visible as silvery sheen on surface water
"Slightly colored"	100	First trace of color may be observed
"Brightly colored"	200	Bright bands of color are visible
"Dull"	666	Colors begin to turn dull brown
"Dark"	1,332	Much darker brown

Note: A one-inch thickness of oil is equivalent to approximately 17 million gallons per square mile.

Source: National Oil and Hazardous Materials Pollution Contingency Plan, June 1970.[5]

Table IV-2

CLASSIFICATION OF AGENTS FOR TREATMENT OF OIL SPILLS

Type of Agent	Active Mechanisms
Dispersant	Causes formation of oil-in-water emulsions or solutions
Sinking agent	Creates high density compound or agglomerate, by chemical or physical action, which sinks
Sorbent	Physically sorbs petroleum and rejects water
Combustion promoter	Provides wick or other action for enhanced combustion
Biological degrading agent	Oxidation by bacterial action
Gelling agent	Chemically reacts with oils to form low density agglomerates
Beach cleaner	Physical remover or dispersion of oil from sand and rock
Miscellaneous unclassified	Examples: chemical booming agents and beach scaling agents

Source: Battelle-Northwest: "Oil Spill Treating Agents: A Compendium," May 1, 1970.[4]

A combination of chemical dispersant supported by auxiliary agitation was recommended by Battelle-Northwest as a general system for oil spill recovery under moderate water conditions and currents (where the dispersant use was not otherwise prohibited).

However, many chemical agents used for treatment of oil spills prove to be more toxic to marine life than the oil they were designed to control. Accordingly, chemical agents in general and dispersants in particular are limited in amount and extent of use permitted, and their use is now prohibited in waters with major marine populations or when wind conditions will carry them onshore within 24 hours.

Also, recovery of chemical agents, especially those designed to disperse, is likely to be inefficient and thus contribute to adverse environmental effects. Dispersants are especially dangerous on beaches or in the littoral zone, since they make oil miscible and allow it to penetrate into sand and crevices.[11]

Thus, the safest generally applicable oil spill cleanup agent appears to be simple straw; it is inexpensive, nontoxic, is genorally available, can be used on beaches or in near-shore waters, and can "gather up to five times its own weight of oily pollutant and still remain afloat."[12] The cellular structure of the straw encapsulates air pockets that provide considerable bouyancy. Straw may be rapidly dispersed by common mulching equipment, and from three to five tons per hour are feasible. Straw requires from three to six hours for maximum absorption of oil and then may be removed by manpower or conveyor systems.

3. <u>Restoration</u>

Restoration of oil-contaminated beaches entails (1) physical pickup of deposited oil, oil contaminated sand, straw, or other debris;

(2) separation (in some cases) of the oil contaminated debris from clean, loose sand; and (3) removal of oil contaminated materials to a suitable disposal site.[13]

Beach contamination represents perhaps the "least serious but most common" element of oil spills.[14] The immediate response of oil to exposure to the environment is to release its volatile components. The degree of volatile loss determines the form of beach contamination. Also, weathering of crude oil changes its physical properties, resulting in asphaltic residue that represents only about 15 percent of the original volume.

Oil sticks to dry, rough surfaces but floats off wet surfaces and may be redeposited by successive tides in the high littoral zone. Thus, natural processes may lead to concentrations of oil that may facilitate its cleanup and removal. "... cleanup methods on sandy beaches (absorption of the oil with straw and mechanical removal of the oiled straw and sand) seem to have little obvious effect on the existing sand biota. However, cleaning the rocky high intertidal zone with hot water removed extensive faunal and floral communities."[15]

Other beach cleanup methods using dispersants, burning, or the like proved either excessively toxic to marine life in the area or were ineffective in removing the oil. Thus, the relatively simple straw and mechanical removal method appears to be most efficient.

Equipment efficiency in cleanup of oil-contaminated beaches was evaluated by URS Research Company (Reference 13). It was found that "motorized graders and motorized elevating scrapers working in combination provide the most rapid means of beach restoration when oil penetration is limited to less than one inch." Front-end loaders were found to be "the most inefficient apparatus tested."

An approach to restoration of oil contaminated beaches by combustion of sand to drive off oil was suggested.[16] However, this system seems certain to be far more damaging to beach biota than would the use of straw and mechanical retrieval. It is not likely that such an approach would be actually used.

C. Present Activities and Organizations

Oil spills are the concern of a number of government agencies at all levels, as well as private organizations. The U.S. Coast Guard has major responsibility for spills in the navigable waters of the United States, together with the Environmental Protection Agency, the Corps of Engineers, and the Navy. Many states and local authorities also have important roles in treatment of oil spills, and participate together with their federal counterparts in research and development and training programs for dealing with these emergency situations. The federal agencies, especially, conduct or sponsor basic and applied research into the effects of oil spills on the environment and into improved means of treatment and cleanup to contain and limit adverse effects. This research is also supplemented by work carried out by the petroleum and transportation industries. The role of academic institutions in analysis of the environmental effects of oil pollution in the coastal zone has been significant, and has provided much valuable data that can be used to guide the design of improved cleanup techniques.

D. Implications for DoD

If present trends continue and increased amounts of crude petroleum and petroleum products are imported to the United States, the risk of larger numbers of oil spills will be increased. To discharge its mission with respect to management of hazardous or dangerous materials in the nation's coastal waters, it will be necessary for the Dod to keep abreast of the state of the art and progress in oil spill cleanup techniques. It will be especially important to ensure that treatment practices are incorporated into DoD's own operations that could lead to oil spills to minimize pollution and to recover spilled oil for reuse as a fuel conservation measure. This will require advanced research and development addressed to the particular needs of the DoD (and in new areas where such work can lead to larger benefits as well).

E. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Research into the means of handling oil spills on the open sea or exposed coastlines without undue loss of oil or dispersion onshore.
- Develop improved means to remove oil from damaged vessels to prevent its escape and facilitate salvage of the vessels.
- Develop portable storage containers for oil recovered from coastal or inland waters.
- Develop practical navigational aids and/or traffic control systems to assist in preventing spills through collisions.
- Develop improved means of monitoring the environmental impact of smaller but more frequent spills that may occur as a result of routine operations at coastal installations.

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CHAPTER SEVEN--MATERIALS HANDLING AND DISPOSAL

I--WASTE MANAGEMENT--AN OVERVIEW

I WASTE MANAGEMENT--AN OVERVIEW

A. Statement of the Problem

Significant strides have been made in achieving general awareness of the need for rational management of wastes from all sources. However, the technical problems inherent in the management of various types of wastes are so diverse that correspondingly diverse management techniques are required.

Every waste management situation calls for the integrated application of some or all of the following tactical steps:

- Reduced generation of waste (by means of process or materials changes)
- Collection
- Transport
- Storage
- Pretreatment (e.g., size reduction, compaction, magnetic separation, air classification)
- Recycling and reuse of separated components
- Treatment (e.g., incineration, pyrolysis, biodegradation, neutralization, detoxification)
- Ultimate disposal of wastes or of treatment residues (e.g., landfill, ocean dumping, deep well disposal, burial in salt mines).

The first measure, which may be termed "avoidance of waste," is clearly preferred wherever it can be practically invoked; however, it is often either technically infeasible or economically impractical. The threat posed by wastes of various types has led several cognizant agencies to challenge the adequacy of this essentially passive approach,

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which often delays the identification of problems until after adverse effects have become so serious in extent and degree that they may be virtually irreversible.

To address the problem of solid waste management in a positive, active manner, it is necessary first to identify the elements that lead to waste materials and to assess the impact that such wastes have on man and his environment. This requires knowledge of waste producing processes in all sectors of the industrial realm, so that those in exceptional amount, of geographical extent, or having deleterious effect can be pinpointed.

Once an adequate waste classification and information methodology has been developed and implemented, attention can be focused on the most efficient application of each tactical step enumerated above.

It is no longer acceptable to make waste management decisions solely on the basis of minimum cost. In particular, it is necessary to include considerations of national resource recovery and conservation, as well as considerations of intermedia environmental effects (e.g., the pollution of air or water while disposing of solid wastes).

B. State of the Art

To avoid redundancies with the chapters of this report devoted to air and water quality, this discussion is concerned only with the management of solid wastes. Moreover, although collection, transport, and storage often represent major fractions of the total cost of solid waste management, these steps generally do not represent the major technological problems. Consequently, this discussion will focus primarily on the steps of pretreatment, recycling and reuse, treatment, and ultimate disposal.

Waste pretreatment techniques in use today are tailored to the ultimate treatment technique that is intended. Where compaction is resorted to, it is primarily as an aid to efficient transport and storage rather than as a necessary precursor of incineration, pyrolysis, or composting. Some form of size reduction is generally needed or desirable virtually before any treatment step, and various types of specialized size reduction equipment have been developed, including hammer mills, flail mills, vertical-axis rasps, drum rasps, roller crushers, and pulpers. Separation of waste components may be resorted to either as an integral part of a recycling process or as a means of facilitating incineration, pyrolysis, or other treatment steps. Such separation may be achieved by hand sorting or by various mechanical methods based on such material properties as particle size (screening), aerodynamic drag (air classification), density (heavy media separation, jigging, table separation, and spiral classification), magnetic susceptibility (magnetic separation), electrical conductivity (electrostatic separation), optical absorption or reflection (optical sorting), and surface tension and wettability (flotation). In certain cases these separation techniques may also serve as posttreatment methods (e.g., separating incinerator residues and metals from glass).

Just as the composition of solid wastes is extremely variable, so is the potential for recycling and reuse of waste components highly variable. Municipal waste is over 50 percent paper and paper products, which represent a relatively poor recycle potential because of their contamination with inorganic fillers, glazes, inks, and the like. Aluminum, steel, and glass represent the other significant recycling opportunities in municipal refuse. Industrial solid waste from individual manufacturing plants is often much more homogeneous than municipal refuse and thereby offers a much better economic incentive for recycle and reuse.

Incineration may be viewed either as a partial waste disposal technique or as a means for recovery and reuse of the fuel value of the waste. The latter viewpoint is much more common in Europe than in this country, but U.S. interest in steam-generating incinerators has grown ever since installation of the pioneer equipment at the Norfolk, Virginia, Naval

Base. Montreal and Chicago have recently installed large steam-generating incinerators, and St. Louis is currently testing the feasibility of burning a mixture of pulverized refuse and pulverized coal in a large electric utility boiler. It is certain that all modern incinerators, whether or not they are designed for heat recovery, will have to comply with much stricter air pollution regulations than in the past. This means that they might be equipped with efficient provisions for complete combustion of evolved organic vapors and with efficient flyash collectors, generally of the electrostatic precipitator type.

Pyrolysis of solid waste, although not currently practiced on a commercial scale, has attracted considerable interest as a potential route to recovery of the waste's energy content in the form of a clean fuel gas or fuel oil, both of which are in increasingly short supply.

Composting of municipal waste has had a discouraging history in this country. Although the technical feasibility of producing a satisfactory compost product has been demonstrated in a number of plants, it has invariably proven to be impossible to find adequate markets for the product. Chemical fertilizers are so cheap and effective that most farmers do not want to be bothered applying compost, even if they could get it at no charge.

Each of the above treatment techniques results in a large reduction in waste volume but still leaves a residue that must be disposed of. For ultimate disposal, current practice consists of the placement of wastes or residues on or in the land or in the ocean.

There is currently a concerted effort to abolish or outlaw most open dumps and to replace them with properly engineered and operated sanitary landfills. If adequate land is available within reasonable hauling distance, landfill generally represents the least costly waste disposal method. However, the availability of suitable sites is rapidly decreasing, particularly near congested urban areas. Moreover, it has been demonstrated that serious impairment of ground water quality may result if landfill sites are not appropriately selected.

Ocean dumping has been the method of choice for many noxious or hazardous wastes (as discussed in Section II of this chapter). However, concern about the resulting impacts on marine biota, is increasing, and the trend is toward tighter regulations and restrictions regarding disposal at sea. Ultimately, it may be necessary to restrict ocean dumping to the deep waters beyond the continental shelves, which would make this technique prohibitively expensive for most wastes.

Burial in salt mines has been proposed for disposal of two principal types of wastes, namely, long lived radioactive wastes and water-soluble salts recovered from industrial processes. In each case, the object is to prevent the hazardous or noxious material from ever coming into contact with surface or ground water.

C. Implications for DoD

By executive order of the President, the DoD has been ordered to take appropriate pollution abatement measures to ensure that its waste management practices at all personnel bases, manufacturing and commodity centers, transportation centers, and naval vessels comply with all present and projected federal and state water and air quality regulations.

Probably the most significant area of concern at present is that relating to the major arsenals of the Army Munitions Command at which a number of major pollution problem areas have been identified. At Edgewood Arsenal (the center for chemical warfare items), the main areas of concern are the following:

- Decontamination and cleanup of facilities and land areas formerly used to manufacture chemical warfare munitions.
- The imminent need to reduce stocks of excess and unserviceable mustard and nerve agents.
- Disposal of large quantities of phosphorus currently retained in a man-made lake.
- Cleanup of pyrotechnic materials that have accumulated in waste streams.

At Frankford Arsenal (the center for ammunition metal parts, primers, tracers, incendiaries, and related materials), the following problem areas are considered urgent:

- Disposal of pollutants (both solutions and sludges) generated as by-products of metal surface treatment operations.
- Disposal of lubricants (e.g., oils, soaps, and solid lubricants) used in metal-forming operations.
- Disposal of explosive wastes produced during manufacture of primers, tracers, incendiaries, and so forth.

At Picatinny Arsenal (the center for explosives, propellants, and pyrotechnics), four major solid waste problems have been identified:

- Disposal of explosive and propellant wastes.
- Disposal of water-soluble residue from incineration of the "red water" by-product of conventional TNT manufacture.
- Reclamation of nitrocellulose fines.
- Disposal of sludges and soluble salts from neutralization of waste acids.

D. Present Activities and Organizations

The Office of Solid Wastes of the Environmental Protection Agency is the principal focal point for federally sponsored activity toward improved solid waste management, in accordance with the provisions of the Solid Waste Management Act of 1965 as amended by the Resource Recovery Act of 1970. The Bureau of Mines of the Department of the Interior also carries on an extensive program in waste management, aimed mainly at resource recovery by application of mineral processing methods. Each of the above agencies publishes an extensive annual summary of active projects; the DoD also sponsers various projects in the waste management area.*

E. Recommendations for Further Studies

A high priority should be assigned to the development of new or modified manufacturing processes that offer the prospect of reduced generation of wastes. A good example is a new TNT synthesis process, pioneered at Stanford Research Institute under the sponsorship of Picatinny Arsenal, that promises to circumvent the "red water" disposal problem by eliminating the need for TNT purification by the conventional sellite treatment.

The problem of water-soluble inorganic wastes is invariably a thorny one, deserving a maximum effort toward developing economic methods for recycle or reuse.

An adequate waste classification and information methodology should be developed, capable of guiding the DoD in identifying its most serious waste management problems. Such a methodology should include quantitative evaluation of each waste production volume, geographic distribution, disposability, hazard potential, and potential for recycle or reuse.

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* Appendix C, AR-91.

CHAPTER SEVEN--MATERIALS HANDLING AND DISPOSAL

II--WASTE CLASSIFICATION AS A TOOL IN HANDLING, MANAGEMENT, AND DISPOSAL

II WASTE CLASSIFICATION AS A TOOL IN HANDLING, MANAGEMENT, AND DISPOSAL

A. Statement of the Problem

Significant strides have been made in achieving basic awareness of the need to control industrial solid wastes, but no universal solutions to this problem are available or on the horizon. The one certain method for addressing the solid waste management problem in the United States is to reduce the amount of waste produced; however, this is often neither feasible nor practical. The threat posed by solid wastes of various types has led several cognizant agencies to question the adequacy of this essentially passive approach, which often results in problems of solid waste management being identified only after the extent and degree of adverse effects have become evident.

To address the problem of solid waste management in a positive, active manner, it is necessary to identify the elements that lead to waste materials and to assess the impact that such wastes have on man and his environment. This process requires knowledge of waste producing processes in all sectors of the industrial realm, so that those in exceptional amount, of geographic extent, or with deleterious effects can be isolated and so that attention can be focused on the immediate treatment, disposal, recycling, or long term control. In short, real progress in solid waste management requires rational classification of waste materials, their properties, and their implications for environmental quality measured in terms of both effect on man and on ecology.

A methodology for ordering information on industrial solid wastes and ranking estimated risks to society from these wastes should satisfy certain criteria:

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- The ranking should be based on a quantitative evaluation of production, distribution, disposability, and potential for reuse of solid materials. Population segments with major exposure to solid waste volume or adverse characteristics should be considered.
- The procedure should provide a means of ranking potential solid waste hazards to assess them in terms of potential effects.
- It should be possible to derive definitions of adverse effects of solid wastes from the classification system.
- Provision for inclusion of laboratory evidence should be made in the classification system.
- The knowledge and judgment of outstanding experts in the different fields pertaining to the solution of this problem should be integrated into the process.

The classification system should also take account of the factors described below.

1. <u>Human Exposure</u>

Because of the large number of ways that humans become exposed to solid waste, the system should be devised to ensure that every significant mode of exposure is considered. The identification of high exposure subpopulations should be a necessary part of the methodology. Search procedures for obtaining estimates of human exposure need to be developed that will make maximum use of available information in the production, distribution, and use of solid wastes to determine if estimated exposure values can be obtained for all types of exposure. The major problem, however, is to hold the cost of the estimation process within reasonable bounds. Therefore, development of techniques for obtaining exposure estimates of sufficient accuracy at minimum cost is a major problem to be considered in design of the classification system.

2. <u>Activity of Solid Wastes</u>

A major effort will be devoted to determining what information on the harmful behavior of solid wastes is available for discriminating among materials before analysis and how this information may be used to develop a hazard list. Estimates of two parameters of suspicion based on current information would be desirable for a balanced estimate of hazards. First, an a priori assessment of whether a material will prove to be harmful is needed. Second, an a priori estimate of the degree of strength of the material is required. In short, the activity of solid wastes in respect to their effect on man is determined by the properties of the wastes in addition to their volume and the place of their production.

The expected hazard presented by a solid waste material should be the parameter used in the ranking methodlogy. Hazard is taken to be a function of both man's exposure to the material and the suspicion of harmful activity that can be associated with it.

Several generalizations can be made about available scientific knowledge on industrial solid wastes.

- Several types of materials are considered harmful or hazardous, characterized by inherent properties, volume of wastes, or both.
- Some members of these groups or types of materials do not seem to be problems provided they are tested, since testing can indicate potentials for safe disposal or re-use.
- The incomplete nature of scientific knowledge on solid wastes does not allow rigorous analytical or statistical interpretation. The facts reported require expert interpretation and evaluation based on an intimate knowledge of the field.
- The categories of materials normally considered for industrial solid waste treatment are not as detailed as they could be. There are many classes of solid wastes

from which few, if any, examples have been tested; most of the scientific effort has been devoted to materials already known to be harmful.

- The contribution of industrial groups or individual processes to solid waste character, volume, or hazard is imperfectly known.

Some of the information with regard to specific formulations may be difficult to obtain because of the proprietary nature of industry, but sufficient information has been published on composition and intended use to permit effective predictions of the hazard potential, disposability, or recyclability of solid wastes. For example, considerable flexibility exists to make frequent formulation changes based on economic considerations and geographic distribution patterns. Thus, even within a one- or two-year period, the pollution potentials of certain materials may change significantly. Another recent development that will result in considerable change is the enactment of laws by major cities affecting the disposal and treatment of solid wastes.

3. Recycling and Disposability

Recycling and resource recovery can be viewed as a solid waste management process or as part of a broader program of use of materials. In short, recycling may be viewed narrowly within the constraints of economic feasibility or broadly to encourage industries to practice reuse of materials. Actually, individual materials and products of industrial processes will fall into each of these categories.

Solid waste disposal is also influenced by inherent properties of materials and especially by their amenability to recycling. For example, highly valued materials are less likely to be disposed of than those of lesser value. However, even highly valued materials may be disposed of if they are complexly intermixed with other wastes such that their recovery is impractical, however desirable recovery may be.

An answer to the question of solid waste recycling versus disposal thus depends on knowledge of the relevant materials, the processes that produce them, and the resulting environmental effects of these materials. In addressing this problem, it will be necessary to use a comprehensive methodology that integrates the information and experience of a number of related fields.

B. Recommended Methodology for Preparing a Solid Waste Classification System

A methodology needs to be developed to guide preparation of a comprehensive industrial solid waste classification system. The methodology should take into consideration the limitations in current knowledge noted above. Principal aspects of this methodology appear to be related to the following aspects of industrial solid wastes:

- Generation and processing (including recycling)
- Storage
- Waste collection and transportation
- Disposal or reuse
- Final disposal and volume reduction.

The major requirements of such a methodology are that it be based on the properties of wastes, emphasize probabilities rather than absolutes, and attempt to assess areas for which existing data are incomplete.

The methodology relies on the properties of waste materials for a variety of reasons. The classification system is concerned with evaluating individual materials. Estimating waste hazard, disposability characteristics, and physical and chemical character is the most unambiguous and universal approach to waste management, and subject to the least misunderstanding. Many methods and techniques exist for automatically processing information based on such characteristics.

The methodology must deal in probabilities instead of absolutes because of the incompleteness of the available information. For example, before a waste is tested, one cannot be absolutely sure that a waste will or will not be harmful. There are too many examples in the literature of chemcials that do not behave as predicted. Furthermore, for classes for which little testing has been done, only a low level of confidence can be placed in estimates of harmful effects. Finally, many of the chemicals that will be of concern to the solid waste classifications system will be incompletely or poorly defined structurally; consequently, not all the factors that could influence assessment of adverse effects, reuse, or disposability will be known.

The methodology must be capable of tracing industrial wastes in two directions:

- Backward Tracing: solid wastes traced from the mode of human exposure backward through their distribution, production, and natural origins.
- Forward Tracing: solid wastes traced forward through production, distribution, use, and disposal.

Each approach has its advantages. In backward tracing, economies are realized by treating the materials in each exposure mode together rather than separately. Furthermore, exposure in a defined population segment can be traced backward, for example, from a particular industrial use to the original sources of the compounds. Forward tracing allows impurities, contaminants, and waste products to be identified at each step in an industrial process. Statistics on production of industrial chemicals are available to support forward tracing for all commercially significant chemical materials. Forward and backward tracing can ultimately be coordinated to reveal exposure of individual population segments to solid wastes at individual stages in any industrial process.

Population is an important factor in an industrial solid waste classification system. A particular segment of the population may exhibit a significantly different effect for certain wastes. These population elements are normally characterized oy occupation, age, sex, race, income, geographic location, and so forth.

The classification should permit an iterative refinement of descriptors of industrial solid wastes; any initial system will require revision and updating with new information. However, the system itself can also aid in directing future research or study into areas where the least precise data exist at present.

The hazard of any industrial solid waste is a function of the inherent properties of that material and of human exposure. A valuable tool for implementing the above methodology in assessment of these variables is a decision tree that logically represents classes of solid wastes that pose potential problems.

The general shape of the activity tree should be designed to facilitate the classification of solid wastes of concern to the classification system by asking a series of questions about their properties and quantity. These questions are in the form of: "Is the material a --- type?" or "Does it contain ---?" Each of these questions would be represented by a branch point in the tree or a decision point in the logic of segregating solid wastes into small groups that are expected to behave (when tested) in similar ways. The questions or decision points would be general at the top of the tree and become progressively more specific in descending order. The answers to these questions would determine subsequent questions to be asked about the compound or group of compounds.

The asking of progressively more refined questions at each decision point would allow a group of solid wastes to be divided and subdivided into smaller groups that are more meaningful for estimating harmful activity, potential for reuse, or disposability. This subdividing continues until each group of waste materials can no longer be divided into subgroups with different degrees of suspicion. The end result of processing a large number of materials through the decision tree is to divide them into many groups.

CHAPTER SEVEN--MATERIALS HANDLING AND DISPOSAL

III--HAZARDOUS WASTE DISPOSAL

III HAZARDOUS WASTE DISPOSAL

A. Statement of the Problem

Certain wastes, because of their chemical, physical, or biological nature, are hazardous to public health or welfare and present special problems in waste disposal operations. Evidence of a deteriorating environment has awakened many to the problems that can occur when inadequate disposal techniques are used. Present disposal methods for certain wastes are questioned, and many ask why methods for the appropriate disposal of materials known to be hazardous are not available. Increased quantities of toxic metals or chemicals are showing up in foods. Incidents, such as the transportation and burial at sea of large quantities of nerve gas, have focused public concern on how to dispose of certain materials. Industries are seeking help with their hazardous wastes; municipalities are becoming concerned with industrial wastes reaching their disposal operations.

B. State of the Art

Hazardous wastes comprise primarily the following categories of materials:

- Toxic
- Flammable
- Explosive
- Pathogenic, mutagenic, carcinogenic, and the like
- Radioactive

The techniques that may be applied for management of hazardous wastes are quite specific to the type of waste.

Flammable and explosive wastes can generally be satisfactorily disposed of by controlled incineration (preceded by dilution, in the case of some explosives). Many toxic wastes are also either combustible or decomposable by heat and therefore may be detoxified by incineration. This also applies to pathogenic wastes in general.

Many inorganic wastes that are toxic, carcinogenic, or mutagenic may be converted to an insoluble or less toxic form by appropriate chemical treatment. However, since no material is completely insoluble, the problem of ground water contamination by landfilled residues must still be taken into account.

Probably the most difficult waste management problem is that of disposal of long-lived radioactive wastes. These cannot be permitted to enter the environment at all and must be stored with complete vigilance until their radioactivity has decayed. The currently favored long term management strategy is to immobilize long-lived radioactive wastes in the form of insoluble ceramic compounds and to store them in selected salt mines where they would not come in contact with ground water.

Disposal at sea or in deep wells in the past has been used for most types of hazardous wastes, but these techniques are now regarded as unsuitable because of serious secondary impacts, such as the generation of earthquakes by deep well injection or the concentration of certain hazardous wastes in the marine food chain. (The latter topic is discussed in Section IV on pesticides.)

Congress recently passed a law (PL 91-512) in which provisions are made to conduct a comprehensive study and devise a workable plan for a system of disposal sites throughout the country capable of accepting, storing, recycling, or disposing of wastes that are hazardous and cannot be properly disposed of by normal waste treatment procedures. The processing categories to be evaluated include incineration, pyrolysis, sanitary landfill, deep well disposal, ocean dumping, ion exchange, dialysis, electrodialysis, reverse osmosis, activated sludge, trickling filters, and aerobic and anaerobic lagoons.

C. Implications for DoD

Full consideration of evaluation factors relevant to the DoD with respect to creation of a system of national disposal sites is necessary. This includes an examination of alternatives to such a system. The assessment of possible alternative approaches will be of value to the DoD, several cognizant agencies, and the Congress as they proceed with deliberations to determine the worth of establishing a system of national disposal sites.

To address the problem of hazardous waste management in a positive manner, it is necessary to identify the processes that lead to waste material and to assess the impact that such wastes may have on man and on his environment. This requires knowledge of waste-producing processes in all sectors of the industrial realm, so that those yielding potentially hazardous wastes in exceptional amounts, with deleterious effects, or of geographic extent can be recognized and dealt with to resolve problems in immediate treatment, disposal, recycling, or long term control.

It is also important to recognize that mere identification of compounds or substances that may be hazardous in themselves (or in sufficient concentration) does not necessarily represent the possible effects that such materials may have on the environment or that such materials present actual problems in disposal. To ascertain the nature of the hazardous waste disposal problem, it is necessary to discriminate among the materials that actually present environmental hazards and those that do not.

A major effort is being devoted to determining what information on harmful behavior of process wastes is available for discriminating among materials before analysis and how this information may be used to develop a hazard list. Estimates of two parameters of suspicion based on current information are desirable for a balanced estimate of hazards. First, an a priori assessment of whether a material will prove to be harmful is needed. Second, an a priori estimate of the degree of strength of the material is required. In short, the activity of hazardous wastes with respect to their effect on man is determined by the properties of the wastes, in addition to their volume and the place of their production.

The expected hazard presented by a waste material should be the parameter used in the ranking methodology. Hazard is taken to be a function of both man's exposure of the material and the suspicion of harmful activity that can be associated with it.

Several generalizations can be made about available scientific knowledge on hazardous wastes:

- Materials considered harmful or hazardous are generally characterized by inherent properties and volume produced.
- Some members of these hazardous groups or types of materials may be eliminated as problems by appropriate research to find potentials for safe disposal or reuse.
- The incomplete nature of scientific knowledge on wastes does not allow rigorous analytical or statistical interpretation. The facts reported require expert interpretation and evaluation based on an intimate knowledge of the field.

Some of the information with regard to specific formulations may be difficult to obtain because of the proprietary nature of industry, but sufficient information has been published on composition and intended use to permit effective predictions of the hazard potential, disposability, or recyclability of wastes and their intermediates. For example, considerable flexibility exists to make frequent formulation changes based on economic considerations and geographic distribution patterns. Thus, even with a one- or two-year period, the pollution potentials of certain materials may change significantly. Another recent development that will result in considerable change is the enactment by major cities of laws affecting the disposal and treatment of solid wastes.

Recycling and resource recovery can be viewed as a hazardous waste management process or as part of a broader program of use of materials. In short, recycling may be viewed narrowly within the constraints of economic feasibility or broadly to encourage industries to practice reuse of materials. Actually, individual materials and products of industrial processes will fall into each of these categories.

Hazardous waste disposal is also influenced by inherent properties of materials and especially by their amenability to recycling. For example, highly valued materials are less likely to be disposed of than those of lesser value. However, even highly valued materials may be disposed of if they are complexly intermixed with other wastes such that their recovery is impractical, however desirable recovery may be.

An answer to the question of hazardous waste recycling compared with disposal thus depends on knowledge of relevant materials, processes that produce them, and resulting environmental effects of these materials. In addressing this problem, it will be necessary to use a comprehensive methodology that integrates the information and experience of a number of related fields.

A methodology for evaluation of possible approaches to disposal sites for hazardous wastes needs to be developed to guide assessment of alternatives and their characteristics. The methodology needs to take into consideration the limitations in current knowledge noted above. Principal aspects of this methodology appear to be related to the following sequential aspects of hazardous wastes:

- Generation and processing (including recycling)
- Storage
- Waste collection and transportation
- Disposal or reuse
- Final disposal and volume reduction.

The primary characteristics of such a methodology are that it is based on the properties of wastes, it emphasizes probabilities rather than absolutes, and it attempts to assess areas for which existing data are incomplete.

The methodology relies on properties of waste materials for a variety of reasons. It is concerned with evaluating individual materials, and estimates of waste hazard, disposability, or reuse are main objectives. Of the many methods of describing hazardous wastes, that of determining their physical and chemical characteristics is the most unambiguous and subject to the least misunderstanding. Many methods exist for automatically processing information based on such characteristics.

The methodology must deal in probabilities instead of absolutes because of the incompleteness of the available information. For example, before a waste is tested, one cannot be absolutely sure that a waste will or will not be harmful. The literature contains many examples of chemicals that do not behave as predicted. Furthermore, for classes for which little testing has been done, only a low level of confidence can be placed in estimates of harmful effects. Finally, many of the chemicals that will be of concern to the national hazardous wastes disposal system will be incompletely or poorly defined structurally; consequently, not all the factors that could influence assessment of adverse effects, reuse, or disposability will be known.

A potentially serious problem at disposal sites is the possible interaction among waste materials. Without careful planning, it is conceivable that waste materials could be mixed together to create potentials for greater adverse environmental effects than the wastes would represent individually.

Knowledge about wastes and their characteristics needs to be completed by knowledge of the environmental factors at candidate disposal sites. It will be important to determine the geological, hydrological, and soil conditions present at possible disposal sites to ensure that natural processes do not entirely or selectively transport waste materials and their harmful derivatives from the site. Otherwise, there is a possibility of counteracting the purpose of the disposal site concept and possibly creating worse conditions. Thus, it is conceivable that the actual conditions in a particular area would act as an economic deterrent to creation of suitable disposal sites.

D. Present Activities and Organizations

In addition to the research activities of the EPA, the Bureau of Mines, and the DoD, as cited in the previous section (Overview of Waste Management), the activities of the AEC in regard to disposal of radioactive wastes should be mentioned. Each of the above agencies publishes an extensive annual summary of active projects.

To accomplish its assignment from Congress in regard to a comprehensive evaluation of the concept of national disposal sites for hazardous wastes, the EPA has funded five research contracts respectively having the following scopes:

- Identification of hazardous wastes, their effects on man, and current handling practices.
- Evaluation of current and recommended processes for handling specific hazardous wastes at national disposal sites.
- Development of conceptual designs for national disposal sites, estimation of processing costs, and determination of optimum site locations.

- Determination of public acceptance of and legislative attitudes toward the concept of national disposal sites.
- Evaluation of alternatives to the use of national disposal sites.

The contractors involved in the above studies are Booz, Allen and Hamilton Applied Research, TRW Systems, Hummro, A. D. Little, and Battelle-Northwest.

E. Recommendations for Further Studies

The principal research needs appear to be in the area of alternatives to the use of national disposal sites. This requires detailed development of the following technologies, specifically for each waste type:

- On-site disposal at the plant or site where the waste is generated.
- On-site recycling (as-is, or after chemical or other types of conversion).
- Transportable disposal equipment taken to the waste, instead of shipping the waste to a disposal site.
- Minor modifications to existing city, county, state, or other disposal sites, so that these sites would be able to handle certain hazardous wastes.
- Offsite disposal by specialist private companies.
- Offsite recycling or conversion.
- Partial use of national disposal sites, for some wastes only.
- Waste avoidance at the source, by production process changes.

Hazardous waste management, like general waste management, needs the development of an adequate waste classification and information methodology, so that high priority problems can be pinpointed for remedial action. The current EPA programs are a step in this direction, but should be augmented by studies focused more directly on DoD problems.

CHAPTER SEVEN--MATERIALS HANDLING AND DISPOSAL

IV--PESTICIDES

IV PESTICIDES

A. Statement of the Problem

In late 1971, the President's Council on Environmental Quality retained SRI to evaluate the feasibility of establishing an environmental indicator system for pesticides and to review and summarize the role and activities of various federal governmental agencies in the broad pest management/pesticides/environmental quality area. During this work interviews were conducted with more than 75 governmental representatives, including Col. Harlan Fowler, Executive Secretary of the Armed Forces Pest Control Board, and Dr. Harold Russell, Chief Entomologist of the Corps of Engineers. The information gathered from them contributes significantly to the background for this discussion.

The currently heralded national problems with pesticides are generally associated with:

- An increased public awareness of potentially adverse effects on wildlife flora and fauna resulting from an interface with pesticide chemicals that have short term (immediate toxicity) or long term (cumulative toxicity) hazard characteristics.
- Risks to humans resulting from increased use of products with high mammalian toxicities and from a growing understanding of the adverse epidemiological effects of certain products.

Administrators and legislators responsible for dealing with these and other related problems are experiencing considerable frustration in arriving at practical and expeditious solutions because of a number of complexing factors:

- Pesticides are deliberately introduced into the environment in attempts to solve the problems caused by certain insects, plants,

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bacteria, viruses, and other pests (e.g., crop, structural, and other economic damage; public health improvement; environmental management).

- An important but often overlooked difference exists between the too common, oversimplistic public concept of a general pesticide problem and the tremendous number of specific materials actually used and that require some kind of control--each with different molecular and chemical properties, toxicities, tonnage and functional use patterns, regional distribution characteristics, and environmental impacts. More than 250 specific chemicals are used in the United States (excluding diluents, solvents, and other components of formulated products) in over 30,000 registered products and formulations.

- In several important public health and agricultural areas, the combination of growing resistance to chemicals by pests (primarily insects), plus restrictions on the use of a number of especially hazardous or persistent products, has only represented problem transfer, in other words, some reduction in the environmental distribution of certain chemicals has been achieved at the expense of an increase in certain original public health and economic damage pest management problems.

- Concern over environmental saturation with chemicals and interest in alternative (nonchemical) means of effective pest control require detailed ecosystem and related data that may not be currently available (or funded for collection) to formulate adequate yet safe management programs.

- The gradual recognition that man must now pay more attention to ecological/environmental systems management from which pesticides can no longer be conveniently isolated similarly implies a need for much more basic information and integrated knowledge than now available. Expectations for immediate, lasting solutions need to be tempered by the understanding that these solutions will take time to develop.

- In a number of agricultural areas, pressure to reduce or eliminate reliance on chemical pest management without a concommitant review of agricultural product market standards required of packers and growers leads to obvious conflicts that could have unintended but important environmental social consequences.

- No great theoretical difference exists between the distribution of pesticides and of other chemicals in the environment, although pesticides have been isolated from current governmental programs covering the environmental diffusion of other "toxic substances."

B. State of the Art

Most governmental agencies have some involvement with pesticides, much of which is limited to the "simple" use of certain products in local pest control projects. DoD activities tend to fall into this classification, and the Department is fortunate that its problems do not approach the scope and political complexity of those in the Department of Agriculture (USDA); Interior (DOI); and Health, Education, and Welfare (HEW); and in the Environmental Protection Agency (EPA). Pest management and pesticide use activities within DoD can be grouped into three broad functional categories as shown below.

Function	Remarks
Internal pest management	In common with other agencies, divisions of DoD have day-to-day problems that involve some degree of pest control, e.g., structural pest control in buildings; weed control on airfields and bases; storage control for inventories of supplies; microorganism control in fuels, control of disease vectors and nuisance pests to ensure the health, welfare, and performance of personnel; control of certain marine biota on ships, docks, and other naval facilities; control of aquatic weeds and other pests, and insects at dam sites, waterways, recreation areas, and other sectors of responsibility for the Corps of Engineers. DoD encounters a broad range of control problems in some of these areas because of the worldwide scope of activities in tropical and other regions with specialized pest profiles.
Warfare	Military use of certain herbicidal chemicals such as defoliants in campaigns in Vietnam is no secret. Military biological and other chemical weapons research often derives from--or more commonly contributes to--basic chemical research that identifies chemical molecules with pesticidal properties.
Quarantining	Within the past few years DoD has established (in conjunction with the USDA, and the Public Health Service of HEW) more effective means of "de-pesting" ships, vessels, and

Function	Remarks
Quarantining (continued)	their cargoes moving within areas of occupation to avoid or minimize the potential spread of pests between countries.

C. Implications for DoD

The DoD already is engaged in extensive programs for the control of certain pests, particularly arthropods. One of the more immediate problems facing DoD concerns the disposal of unused and unwanted pesticides that have accumulated at various international bases and theaters of operations over the past 30 years in the fight against pests. It is apparent that a large part of this problem is one of management, i.e., identification, classification, and collection--if necessary--of the materials concerned. The mechanics of disposal may be more associated with economics than technology, i.e., what ways--if any--are available to safely dispose of these products on site to avoid the expense of collection for centralized disposal. The specific details and magnitude of this problem (e.g., types, volumes, ages, containerization, and locations of the materials) will require careful analysis to establish optimum disposal programs. Generally speaking, mechanisms for disposal embrace functional environmental diffusion (consumption for the use intended) in areas where use restrictions are not warranted, deep well or deep water disposal, incineration (oxidation), and neutralization deactivation through natural aging or chemical treatment.

Container disposal is a unique part of the problem. Ideally, pesticide containers should be durable, safe and easy to use, and compatibly disposable with the volume and properties of the specific material contained. Most existing container systems do not meet all these requirements, and discussions with the Federal Working Group on Pest Management (whose Safety Panel is currently working on container, disposal, and incineration problems) indicate that container companies have not been aggressive in designing products that meet these needs.

In addition to undertaking periodic studies of the environmental impact of specific internal pest management programs, DoD may wish to study and accumulate data on the long term ecological impact on, and regenerative capacity of, areas that have received heavy doses of chemical defoliants (and possibly other chemicals, bombs, and so forth).

A brief summary of government agencies indicates that certain component branches of DoD have excellent reporting data systems for internal pest management and pesticide consumption programs. DoD may devote additional effort to further improving these systems and to aiding in the development of standardized systems that can be used throughout the federal government for the collection and organization of similar data.

D. Recommendations for Further Studies

Among the areas of pest control within DoD that could logically provide tasks for further study are to:

- Explore new or unique disposal techniques at foreign bases and theaters of operation not only geared to DoD's own needs but also applicable to disposal under other (typical commercial) conditions. Also, a certain amount of research is needed on improved container design.
- Conduct additional research on the long term impacts on areas that have received heavy doses of chemical defoliants to determine the costs and steps necessary for man to restore such areas to a productive state. A test defoliation area of about three square miles at or around Eglin Air Force Base would lend itself to such a study.
- Allocate additional effort to standardizing data reporting systems throughout the federal government and coordinate the results with current work on data computerization by the Federal Working Group on Pest Management.

CHAPTER EIGHT--DATA MANAGEMENT AND MONITORING

I--INTRODUCTION AND OVERVIEW

I INTRODUCTION AND OVERVIEW

The President's Executive Orders 11507 and 11514 provide guidance and direction to the federal agencies in the environmental protection areas. The Department of Defense Directive 5100.50, 23 June 1970, Protection and Enhancement of Environmental Quality, responded to these Executive Orders by establishing DoD policies, assigning responsibilities to DoD components, and setting DoD-wide standards for environmental protection.

Additionally, this directive sets forth requirements for coordination between DoD components on overlapping environmental problems, for full cooperation with other federal agencies, and for compliance with published standards and crtieria relating to DoD applicable pollution abatement that are promulgated by federal, state, and local governmental agencies. The DoD and DoD components have established committees and special groups to achieve such coordination and cooperation.

Each of the military services has been responding to the DoD Directive 5100.50 by issuing individual directives, instructions, and so forth, for environmental protection within their purview. Each component of DoD is charged with the responsibility to monitor its individual actions and to provide plans and ensure adherence to standards, regulations, and directives. The Navy has taken the lead in initiating studies to lead to an environmental data base system, and the other service arms are preparing to follow suit.

At the present time there are no DoD coordinated efforts for collection of environment data or attempts to organize a DoD environmental data base. The individual efforts being undertaken by DoD components are

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characteristically aimed at each individual component's responsibilities for environmental protection, and overlapping areas of interest are not yet being addressed.

The success of the coordination of DoD activities depends vitally on ready access to environment-related data to at least keep abreast of DoD activities as they affect the environment and to ensure that DoD components are meeting DoD environmental protection requirements with neither excessive overlap nor insufficient cooperation. The most promising solution to this problem is believed to be the use of a Data Management System (DMS) that provides for the desired capabilities of ready access to well organized environmental data. The following sections will outline several factors that are required for the implementation of such a system and the benefits that can be accrued from it.

A. Environmental Data Bases Within DoD

It is expected that each DoD component will be building data bases of environment-related data to support their environmental protection responsibilities. The Army, Navy, and Air Force have a need for environment monitoring programs that will provide measurement data on their individual operations. Some of these programs are in the first operational or experimental stages and others are in the planning stages. Other types of data to reside in the service data bases are collections of:

- Standards and directives applicable to the individual service
- Operational statistics
- Equipment and facilities that affect the environment
- Abatement practices, plans, and results
- Construction and environmental impact-related data
- Environmental protection technology data as applicable to each service.

The other DoD components, e.g.. Defense Supply Agency, Defense Communications Agency, will require data similar to some of the above categories as they apply to their responsibilities. These agencies do not have the broad operational activities that the services perform. They do have responsibilities for extensive support facilities, equipment, and material that they provide to the services. In so doing, these agencies are engaged in construction and implementation of systems that can have effects on the environment. Thus, these agencies need to collect data on the projected and present activities which they are managing to determine their adherence to environmental standards and their progress in pollution abatement planning.

These several data bases will be implemented in various ways--some will be mostly manual collections and storage of data and some will require a high degree of automation to manage the data in a cost-effective manner. These data bases will overlap if there is not a coordinated effort to monitor the development of data bases and data management systems at a higher DoD level.

One example of the difficulty in following environmental data base development is the present proliferation of all types of data bases within the services at this time. Each service has a very large number of data bases now, and each is continually creating data bases that could provide environment-related data for one purpose or another. The Navy has several System Commands, some of which have funded and developed over a hundred data bases. It is even quite difficult to keep track at the present time of the data bases and their status because of insufficient current information about existing specimens. What is needed is a current survey of data bases throughout DoD that exist and that are being developed and/or planned.

B. DoD Environmental Data Management Program

The previous discussion has shown a need for coordination of data collection, storage, and retrieval activities that are being done or are being planned within DoD.

The effectiveness of DoD environmental research programs depends on data related to the cause, effect, and abatement of adverse impacts on the environment and on the planning and status of environmental protection actions. These data are often voluminous, dispersed, incomplete, and sometimes they exist only in their raw state. Thus, these data require collection, organization, analysis and reduction to be used for determination of environmental effects.

The most effective tool for providing a mechanism for handling and processing data is a general Data Management System (DMS). A DMS can provide the means by which the location of required data in usable form can be readily found and the ability to access data and perform analytical operations on it to obtain information on environmental conditions, abatement status of pollution control programs, and on environmental protection plans and standards/regulations/directives.

A DMS can be designed in many different ways and depends on basic assumptions as to the amount of data to be stored in the system, the particular functions the system incorporates, the use of external environmental protection data bases, and the methods by which data will be transmitted between data base centers. The establishment of a DoD Environmental Data Management Program (EDMP) would be a logical approach to determine the specific DMS implementation that would be most suitable for DoD.

The first step is to specify in detail the objectives of EDMP for DoD as described above. The detailed list of objectives is used to establish a foundation for the alternative DMS structures that can be postulated. The EDMP would be concerned with: the data bases maintained by DoD components; the environmental monitoring programs established or planned by each service; the functions that each DoD component would perform to provide the data required for DoD to assess each component's environmental protection activities and the functions performed at the DoD level to use these data; and the facilities available to DoD to implement a DMS (e.g., data transmission, data processing centers).

Each of the above described EDMP areas of concern must be examined and alternatives delineated. For example, the functions performed at the DoD level in environmental protection will require ready access to data that are organized and processed for efficient use. These functions include planning, resource management, evaluation of ongoing programs and assessment of DoD-wide conformance to environmental protection standards and directives. The manner in which these functions are performed for environmental protection will affect the design of a DMS, since the data and the data's organization required for these functions will be different for each different function implementation, i.e., each function is composed of several complex, interwoven components that require individual sets of data that characterize the operation of each component; also, data that describe the interaction between components are needed.

All the areas of concern will not be discussed here; however, one area will be addressed to indicate how the problem of examining these areas could be approached to lay the foundation for a DMS design. The area considered is the coordination and the effectiveness of DoD environmental data monitoring and collection that individual components would carry out. To determine if data collection operations will meet DoD directives and regulations, the data defining the DoD impact on the environment must be identified, which in itself is no simple matter. One approach to identifying such data is to structure an Environmental Effects Framework (EEF) that can be used to link DoD actions with environmental effects. It is recognized that while a specific management action is more or less directly linked to a desired effect, the indirect and higher order effects will become apparent through the EEF cause-effect relationships. Thus the EEF can provide a basis for structuring an environmental effects predictive capability. The salient features of the EEF are described in Section II of this chapter.

CHAPTER EIGHT--DATA MANAGEMENT AND MONITORING

II--ENVIRONMENTAL EFFECTS FRAMEWORK

II ENVIRONMENTAL EFFECTS FRAMEWORK

A. Generation of Environmental Effects

The environmental effects framework (EEF) is developed by tracking material through the processes by which it is ultimately disposed in the environment and interacts with other uses of the environment. A simplified and generalized scheme for this is shown in block diagram form in Figure II-1. The main segments of the EEF have been designated as:

- Production-consumption
- Waste discharge
- Environmental quality
- Biological effects
- Socioeconomic impacts

1. Production-Consumption

The production-consumption cycle converts input factors into useful output and unwanted residuals. This formulation makes a distinction among raw materials, consumable supplies, and the facilities by which they are utilized in processing, production, and operations. The production-consumption cycle for a DoD facility may be characterized by the following sequential stages:

- Design and planning
- Production
- Distribution
- Consumption
- Retirement

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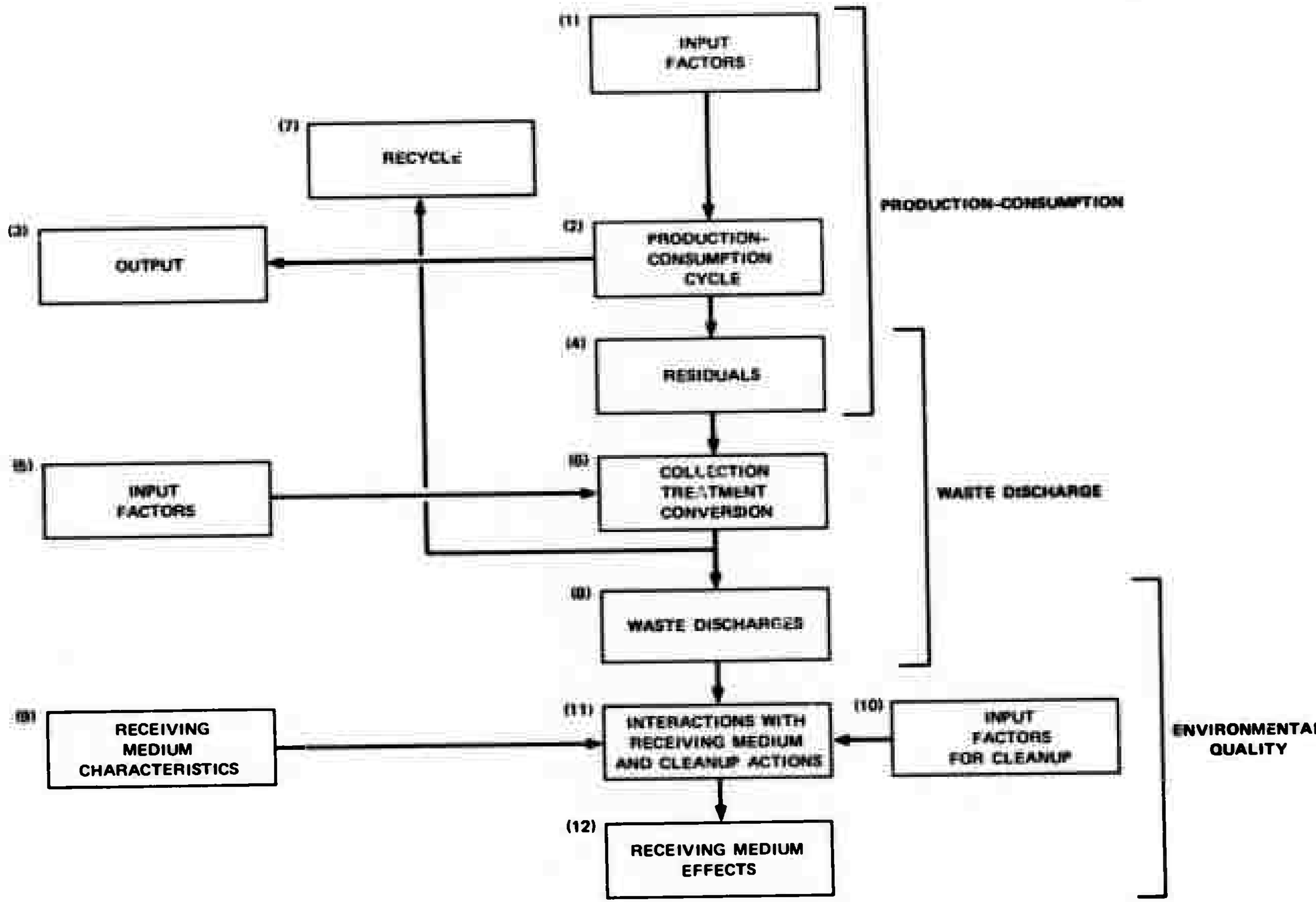

FIGURE II-1 ENVIRONMENTAL EFFECTS FRAMEWORK

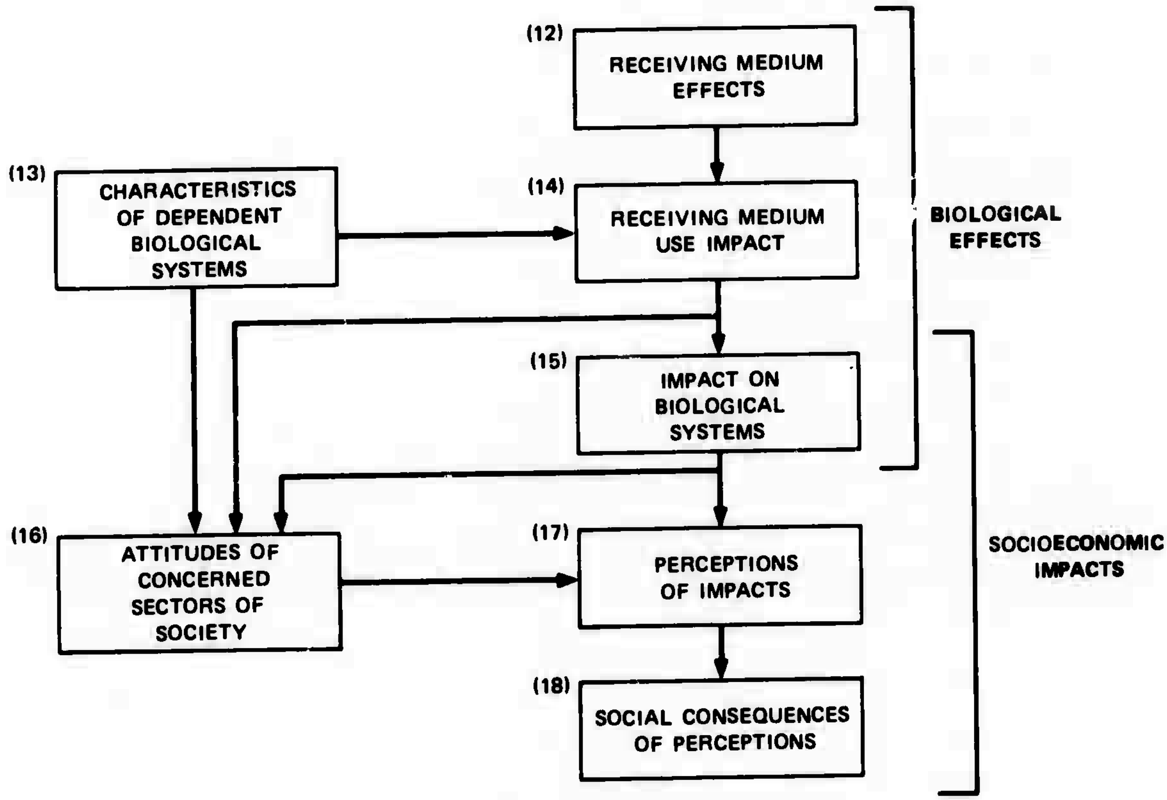

FIGURE II-1 ENVIRONMENTAL EFFECTS FRAMEWORK (2) (Concluded)

At each of these stages in the life cycle of a DoD facility, residuals may be generated. The basic concept is that of an energy-materials balance. This may be set up on the basis of the steady state operation of a DoD facility or complex of facilities. It may be based on a unit of output or input factors at a particular stage in the production-consumption cycle. It may be the cumulative residuals generated on the basis of a facility or class of facility carried through all or part of the production-consumption cycle. The important point is that varying the dimensions of the system on which the energy-materials balance is to be struck determines the type of DoD question that may be addressed. Another important point is that the energy-materials balance concept is a powerful tool for accounting for all residuals (see also Chapter Four).

2. <u>Waste Discharge</u>

The residuals generated by the production-consumption cycle are candidates for recovery as valuable scrap or for disposal as unwanted wastes. This segment of the EEF is concerned with the latter category of residuals. Within limits the residuals may be collected, treated, or transformed by facilities so that they may be disposed of in a more acceptable manner. For example, sewage is transformed into gas which may be burned and sludge which may be disposed of on land or burned in an incinerator. Sound may be converted to heat. Waste heat may be disposed of to water bodies or directly transferred to the atmosphere. Certain gases may be dissolved in solutions and disposed of as a liquid or precipitated for disposal as a solid. Airborne particulate matter may be collected as a solid. The important point is that residuals are not destroyed; they are merely disposed of in another form or in a different medium.

The processing of residuals by facilities is analagous to the production-consumption cycle, thus the comments made above under that category hold equally well in this segment of the EEF.

3. Environmental Quality

The media--air, water, and land--on which wastes are discharged have a finite capacity for diluting, dispersing, attenuating, assimilating, or holding wastes. When the aggregate waste discharges in a region exceed this capacity, then the environmental quality of the region suffers. The geographic limits of the region that can be affected by waste discharges at specific locations are determined by complex natural characteristics of the receiving media and will not correspond for the different media. The extent to which the environmental quality characteristics of a receiving medium can be affected by waste discharges in terms of both space and time provides further information on needed data.

Waste materials will interact with the receiving media and will be transformed or removed at rates that are characteristic of the waste material and the available waste handling or assimilative capacity of each receiving medium. In addition, under certain conditions the contaminated receiving medium can be treated or processed to remove certain materials and thereby improve the environmental quality.

4. Biological Effects

The receiving media for wastes constitute the living environment for biological systems. Therefore, a change in the physical or chemical characteristics of the receiving media can affect the life processes of these dependent biological systems. These effects can be directly on an organism itself or can be felt indirectly through the ecological interrelationships of the various species.

The human organism differs from other species in its response to environmental quality in at least two important aspects. Humans can process environmental components to an acceptable level of quality, e.g., drinking water; but humans look to the environment for more than life support needs. Humans use the environment as a resource to support a desired life style or standard of living. These uses have both environmental quality requirements and environmental quality effects. Therefore, when a change in environmental quality occurs because of some perturbation in the usage structure in a region, some uses are made more or less desirable. Benefits are transferred to the sectors of society whose uses are made more desirable or whose increased usage is responsible for the change in environmental quality. On the other hand, other sectors of society find that they must bear an additional burden of cost to process an environmental component to an acceptable level of quality so that they may maintain their desired level of use, or they must reduce their usage.

The shifts in usage patterns that accompany a change in the physical and chemical characteristics of the receiving media cause conflicts among the users of the environmental components. These conflicts result in stresses and disruptions in the social organization through which humans interact.

The organization of biological organisms that are affected by a change in the environmental quality characteristics of a receiving medium presents a further dimension to which DMS user questions may be directed. Some categories for organization include biological classification according to organism types, to a hierarchical ordering, to environmental component dependency, to ecological interrelationships, and to social organization and economic interaction.

5. Socioeconomic Impacts

The social consequences of the impact on biological systems resulting from changes in the environmental quality characteristics of the receiving media depend on the perception of these impacts by groups whose interests are believed to be affected. These perceptions in turn are influenced by the attitudes of these interest groups toward the changes that are perceived and the activities that are believed to be responsible for these changes.

The social consequences that may take place may take many forms. If there are no credible institutionalized mechanisms for addressing the perceived impacts, then these consequences may become disruptive. The basic dimensions for addressing questions to the DMS concerning these social consequences are through catorization of affected social interest groups.

B. Control of Environmental Effects

1. Approaches to Environmental Quality Problems

The ultimate objective of environmental quality management is solving social problems that arise from changes in environmental quality characteristics. Four different approaches can be taken when attempting to solve a social problem. The four types of solutions can be labeled as systemic, preventive, ameliorative, and compensatory. The alternative strategies can be illustrated by four kinds of solutions to the problem of mercury poisoning resulting from humans eating contaminated seafood. A systemic solution would be to provide alternative foods in the diet. A preventive solution would be to stop mercury discharges to the aquatic environment. An ameliorative solution would be to provide care and therapy for the victims. A compensatory solution would be to pay the victims or their survivors for the damages suffered.

The emphasis in the United States by the environmental control regulatory authorities is on the preventive approach to solutions. Since the social problems arise at the end of a long chain of dependent effects as shown by the EEF, this presents many opportunities for intervening at various points in the cause-effect chain to affect the dependent effects. There are few feedback loops in the EEF and so there is little opportunity to influence prior causes.

2. Environmental Quality Control Modes

The preventive approach to environmental control can be applied in three modes:

- Predictive
- Int ıctive
- Remedial

The predictive mode relies on a sufficient knowledge of the cause-effect relationships expressed in the EEF to select appropriate control techniques so that the unwanted effect cannot occur. This is best applied at the planning phase of an operation or the design phase of a facility. The purpose of the Environmental Impact Statement required by the National Environmental Policy Act of 1969, P.L. 91-190, for all federally funded or regulated facilities is to inject environmental considerations into the planning process.

The interactive control mode operates in real time so that an indication of a situation is sufficient reason to expect an undesirable dependent effect. This allows for the possibility of intervening in the cause-effect relationship between the indicator signal and the dependent effect to limit the dependent effect to the extent desired. This control mode also requires a knowledge of the cause-effect relationships, but this knowledge may be adaptive and ad hoc. In other words, it may be largely empirical, obtained through monitoring the control response in a particular situation.

The remedial control mode in essence learns from past mistakes. It is an after-the-fact application of control to prevent similar undesirable situations in the future. If the knowledge about cause-effect relationships so obtained is properly structured and augmented with special studies to fill gaps or to verify relationships, such a control mode can help build an environmental effects predictive capability. This approach to environmental control uses the environment as a working laboratory.

3. Control of Environmental Effects

In practice, an effective environmental quality management program will use all four types of solutions available in all appropriate modes as required by the specific set of circumstances. The ideal is the preventive solution in a predictive mode, but this may not always be possible or even desirable in terms of the practical constraints established by real situations. An idea of the possible kinds of intervention in the cause-effect relationships represented by the EEF that may be exercised so as to influence dependent effects is illustrated in Table II-1. Some of these may not appear to apply directly to DoD activities, but when it is considered that DoD activities are supported directly or indirectly by a wide range of civilian activity, the connection becomes more apparent. For example, a user tax on leaded motor fuel has been often suggested as a means of promoting the use of low lead or lead-free gasoline. While such a tax would not apply to DoD purchases, it would certainly apply to the civilian employees who use their automobiles to commute to their jobs at a DoD installation. To the extent that the DoD installation commuters switch to low lead motor fuel, car pools, or public transportation, the emissions will be reduced and the air quality will be improved.

Table II-1

CONTROL ACTIONS RELATED TO ENVIRONMENTAL EFFECTS

Input Factors

- Control of the use of specific materials
  - Prohibition of specific materials
  - Rationing
    - Price means (user tax)
    - Nonprice means
      - Use permits
      - Licensing of users
  - Specification of composition
    - Licensing of producers
    - Licensing of materials

Production and Consumption

- Control of production output or extent of operations
  - Quantity - licensing of production or operation
  - Quality - product composition or performance specifications
- Control of processes or operations
  - Technology
    - Licensing of facilities, processes, or operators
    - Standards and specifications for design and operation
  - Time and location
    - Land-use control
    - Licensing or permits for each specific instance
    - Restriction to specific seasonal, diurnal, or other temporal characteristics

Residuals

- Control on amounts - specification related to process or operation
- Control on characteristics - physical properties, chemical composition, or biological characteristic related to process or operation

Treatment or Conversion

- Specification of requirements - degree of treatment, types of processes, or level of technology in terms of residuals
- Control of processes or operations
  - Technology
    - Licensing of facilities, processes, and operators
    - Standards and specifications for design and operation

Table II-1 (Continued)

Institutional arrangements
- Specification of administrative control
- Specification of pooling, regionalization, joint use, or use of municipal or commercial facilities

Time and location
- Land-use control
- Licensing or permits for each specific instance
- Restriction to specific seasonal, diurnal, or other temporal characteristics

<u>Waste Discharges</u>

Control of disposal media - specification of discharge mode

Control of discharge characteristics
- Properties - specification of physical properties, chemical composition, or biological characteristics
- Amounts
  - Discharge permits
  - Prohibition of specific materials
  - Specification of mass emission rates, absolutely or relative to some operational or receiving medium property
  - Discharge tax
- Time and location
  - Land-use control
  - Licensing or permits for each specific instance
  - Restriction to specific seasonal, diurnal, or other temporal characteristics

<u>Interactions with Receiving Medium and Cleanup Actions</u>

Apportionment of receiving medium "capacity"
- Prior appropriation
- Administrative rationing
- Use charge rationing

Specification of cleanup-action - cleanup contingency planning

<u>Receiving Medium Effects</u>

Specification of air, water, land "quality" standards
- Physical properties
- Chemical characteristics
- Bioassay characteristics

Table II-1 (Concluded)

Receiving Medium Use Impact

- Control of uses
  - Limitation of uses
    - Use charges
    - Use permits
    - Prohibition by administrative means
    - Prohibition by physical means to limit access
  - Promotion of uses
    - Subsidies for users
    - Facilities to promote uses
  - Declaration of beneficial uses
  - Internalizing "externalities"

Biological Systems Impact

- Specification of air, water, land "quality" standards in terms of biological characteristics
- Declaration of beneficial uses

Perceptions of Impacts

- Specification of public relations programs
- Specification of educational programs
- Specification of information exchange program

Social Consequences of Perceptions

- Administrative compensation program for "damages"
- Contingency plans for dealing with social problems
- Institutionalizing the resolution of social concerns

4. Environmental Quality Management

Several tasks must be accomplished to establish an environmental quality management program. They are to:

(1) Adopt goals, objectives, criteria, guidelines.

(2) Specify appropriate environmental effects management actions to achieve (1).

(3) Specify monitoring, evaluation, and reporting program to support (2).

(4) Organize authorities and responsibilities for the environmental quality management program.

(5) Allocate resources to the various elements to support their authorities and responsibilities.

The environmental quality management program is directly related to function (3), whereas function (3) is specified to support function (2). Functions (4) and (5) are necessary for the entire program. While Table II-1 shows the range of possible environmental effects control actions that may be applied at the various stages of the EEF to affect the outcome of dependent effects, the data needs to support this range of possible environmental control actions are shown in Table II-2.

In practice, an environmental quality management program is limited to a specific set of control measures that are designated as "standards" by the responsible regulatory agencies. The most commonly applied standards limit the amount of a particular waste discharge to a receiving medium. This has certain practical conveniences even though the objective is the control of ambient receiving medium quality.

- The responsibility of a waste discharge can be readily identified. However, once a material has been dispersed in a receiving medium, only in a very few cases can it be unambiguously tracked to its source.

Table II-2

ENVIRONMENTAL DATA NEEDS TO SUPPORT CONTROL ACTION

<u>Input Factor Data</u>

Use rates, duration and time, location

Physical properties, chemical composition, biological properties, public health and handling characteristics, shelf life, perishability, or other chemical and physical transformations

Purchase specifications, unit cost, responsibility for purchasing

<u>Production-Consumption Cycle</u>

Production rates, conversion rates of input factors, operational speed, duration and time, location

Characterization by unit process or operation, equipment specifications, operator qualifications

Capital costs, depreciated and replacement value, operating and maintenance costs, training costs of operators, times to implement

Purchase, operational, and maintenance specifications and responsibilities

<u>Residuals</u>

Generation rates, duration and time, location

Physical properties, chemical composition, biological properties

<u>Treatment or Conversion</u>

Throughput rates of residuals and input factors

Production rates of outputs, conversion rates of input factors and residuals

Other data as under <u>Production-Consumption Cycle</u>

<u>Waste Discharge</u>

Discharge rates, duration and time, location, source, responsibility

Physical properties, chemical composition, biological properties, public health and handling characteristics, degree of reactivity with various receiving media, degree of physical transformation in various receiving media

Table II-2 (Continued)

Receiving Medium Characteristics

Characterization of the natural processes that define dilution, dispersion, attenuation, assimilation, or holding capacity for waste discharges in general

Air--meteorology, diffusion, insulation, photochemistry, sound transmission

Water--hydrology: watershed, ground water, rivers, estuaries, coastal zones, oceans

Ground--geology, soils, and seismic properties

Baseline quality characteristics--physical, chemical, and biological

Interactions with Receiving Medium and Cleanup Actions

Characterization of natural processes and remedial cleanup processes by which the baseline quality characteristics are changed by specific waste discharges

Receiving Medium Effects

Changed baseline quality characteristics--physical, chemical, and biological

Characteristics of Dependent Biological Systems

Characterization of populations, distributions, and ecological interrelationships with respect to receiving medium effects

Nonhuman (plants and animals; aquatic and nonaquatic)

Characterization of effect of environmental quality on life cycle needs (primarily feeding and metabolic processes, and reproduction)

Human

Characterization of effect of environmental quality on life cycle needs (physiological), life style desires (psychological), and on industrial processes

Characterization of social and economic organizations by interests related to receiving medium use

Receiving Medium Use Impact

Characterization of the changes in the use quality of the environment for the dependent biological systems resulting from receiving medium effects

Table II-2 (Concluded)

Impact on Biological Systems

Characterization of the "well-being" of communities of dependent organisms resulting from changes in use of the receiving medium imposed by changes in the quality

- Nonhuman
  - Biomass production rate
    - Total
    - By species (especially "indicator" species)
  - Species diversity index
- Human
  - Health effects (physiological, psychological)
  - Social effects
  - Economic effects

Attitudes of Involved Sectors of Society

Characterization of society in terms of relevant interests

Characterization of relevant interest groups in terms of attitudes toward:

- Environmental quality
- Impacts resulting from changes in environmental quality
- Activities of the DoD

Perceptions of Impacts

Characterization of beliefs of interest groups concerning the impacts of changes in environmental quality on their interests

Social Consequences of Perceptions

Characterization of actions taken by interest groups to ameliorate the perceived impacts of changes in environmental quality on their interests

- The concentration of a pollutant in an emission from an exhaust stack or outfall pipe is high enough to be analyzed accurately, whereas the concentration in a receiving medium may be below the sensitivity of analytical techniques.
- The instantaneous and integrated rates of discharge can be determined.

These conveniences dictate this type of standard even though in many cases the relationship of such standards to the environmental quality characteristics of the receiving medium is tenuous at best. The formulation of rational and equitable waste discharge standards would be greatly enhanced by the development of a predictive capability based on the cause-effect relationships expressed in the EEF.

A waste discharge standard must ultimately be expressed in terms of a monitoring, sampling, and analysis program. For example, although the standard may read that the concentration of mercury in a waste discharge stream may not exceed 5 ppm, what is really implied is that the samples of the stream (which are of a certain size, are taken at a certain frequency, and are taken, handled, and analyzed according to certain methods) shall not exceed the desired concentration limit. The same comments apply to any type of standard--waste discharge, receiving media, biological effects, or social consequences. The data, representing a sample of the universe, will have characteristics related to:

- Accuracy (how well do the results represent reality?)
- Range of validity (to what geographic, volumetric or mass, or population limits does it relate?)
- Perishability (for what period of time is it valid?)

CHAPTER EIGHT--DATA MANAGEMENT AND MONITORING

III--ENVIRONMENTAL MONITORING

III ENVIRONMENTAL MONITORING

A. Monitoring Program Objectives

The design of a monitoring system will reflect a decision about which portion of the EEF is important to DoD. As explained in Section II of this chapter, monitoring is an essential feature of an environmental program for three reasons:

- The agency will be forced to make many decisions that may have far reaching and unpredictable environmental effects on the basis of inadequate information. A monitoring program is needed to follow up these decisions and to detect unexpected or unwanted effects before they become irreversible.
- The data gathered by a monitoring program can be used in the development of improved techniques for the prediction of environmental effects. The need for a reliable means of environmental prediction is acute.
- The data required to determine compliance with standards can be obtained only by a systematic monitoring program.

Therefore, the objectives of the monitoring program must be carefully delineated before design and implementation. These objectives will be based on demand on the resource, desired environmental quality, and imposed constraints.

Because there are relationships between resource demand, use and control activities, physical and chemical characteristics, and environmental effects as shown in Figure III-1, resource management actions taken at any level of dependent effects will affect the other levels. Furthermore, management action taken in regard to any one use will affect other uses directly through its effect on environmental quality and perhaps indirectly

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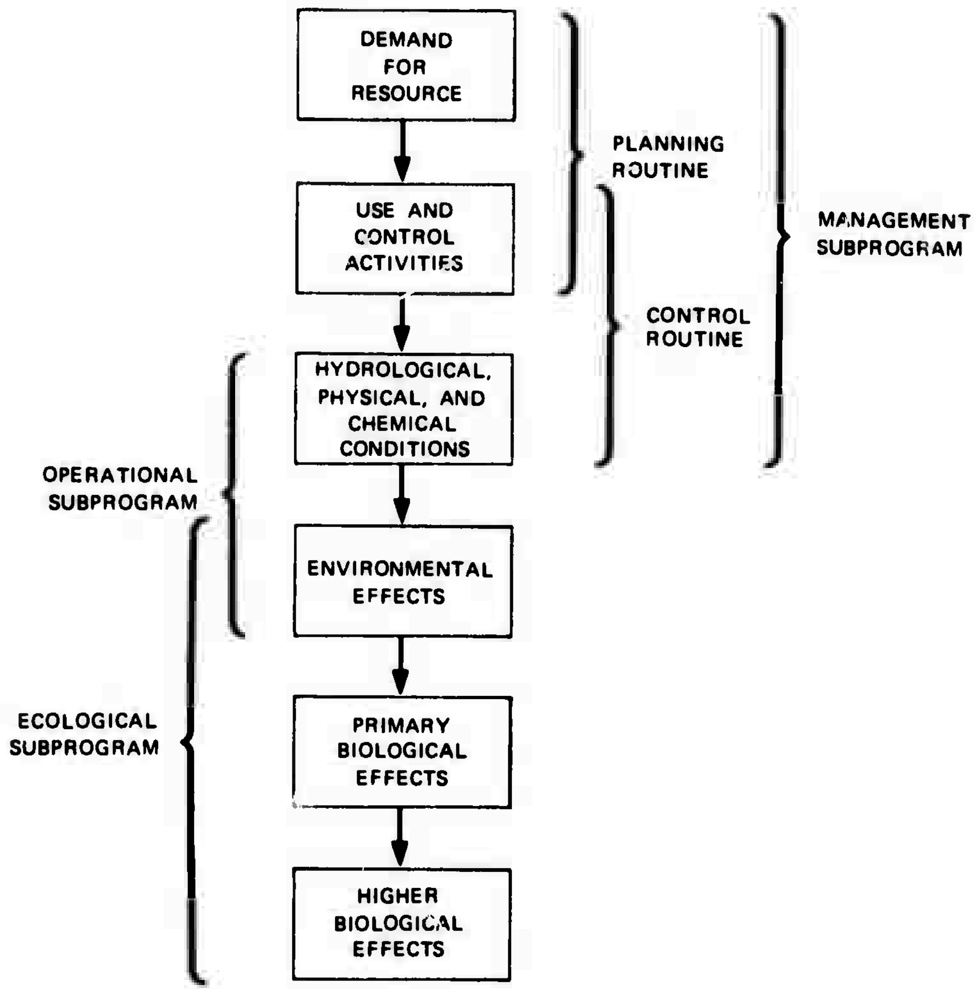

FIGURE III-1 ENVIRONMENTAL PREDICTIVE PROGRAM (SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN BAY) through relationships between dependent effects other than those related to environmental quality.

Many federal, state, and local agencies, as well as private entities, make management decisions that can affect water quality and thereby disturb the balance among resource users. In this situation the actual management of the resource is likely to be the net effect of the power play among agencies and interests.

It is not possible to give a detailed and general prescription for the design of an environmental monitoring program. The primitive state of environmental knowledge, which makes the monitoring program such a crucially necessary tool, also makes its design a highly intuitive process. Moreover, the specific requirements of the monitoring program depend very much on the specific geographic area in which the program is to operate.

To establish a priority among conflicting uses of the resource, information must be available that adequately characterizes these conflicts. To specify the parameters to be monitored and the monitoring characteristics as derived from a consideration of these conflicts, four classes of information are required:

- The measurable parameters related to the conditions and effects of resource use
- A detailed description of the resource-geographical distribution, operational condition, quality conditions or constraints, and their temporal variations
- Environmental quality requirements of the uses of the resource
- Standards of environmental quality.

All four categories are subject to determination on a regular basis in a resource management plan. A resource description of a complicated ecological subsystem can always be improved and requires regular updating through consistent monitoring. In addition, the environmental quality requirements of some uses of the resources are imperfectly or little known. As more information is obtained from the monitoring program, some resource use requirements may change as the value judgments of the user change. This change should be accompanied with a modification to the monitoring system.

B. Monitoring System Description

A minimum monitoring program that will achieve most environmental goals includes five separate but interrelated activities as shown in Figure III-2. These activities are discussed in a broad general sense and would have to be defined more precisely for a particular application.

Based on the state-of-the-art understanding of a resource, its uses and quality requirements of its uses, the possible measurable parameters related to the resource and its use can be evaluated in terms of various characteristics. For example, the characteristics of water are listed in Figure III-3. Point monitoring can be used to measure these parameters at a selected number of points where quality is a problem or may become a problem.

Synoptic monitoring by aerial surveillance can be used to describe the spatial and temporal variance of the parameters between point monitoring stations. In a regular well behaved system, assumptions about the variability of a parameter may be made without supplemental data. However, in complicated systems with daily and seasonal changes or with rapidly changing topography, intuitive and empirical guesses must be augmented by sufficient other data to produce a reasonable assumption.

An established aerial surveillance program can react on relatively short notice in response to special problems. These can be emergency

- Point monitoring
- Aerial surveillance
- Wastewater monitoring
- Resource demand and use monitoring
- Data management system

FIGURE III-2 MONITORING ACTIVITIES

- Relative priority
- Recommended sampling frequency
- Recommended method of sampling and analysis
- Relationship to possible sources
- Associated resource uses
- Effect on use or organism

FIGURE III-3 CHARACTERIZATION OF MEASURABLE WATER PARAMETERS situations requiring prompt evaluation of resource quality problems for the purpose of determining the extent, cause, and if possible the remedy.

All significant facility and industrial discharges should be monitored for quantity and composition. Waste flow rates should be continuously monitored, as should any other relevant parameter that can be conveniently monitored continuously, such as pH. Samples for analysis should be representative of the entire waste during the period between samples. If the waste composition is highly variable, this will require frequent sampling and some method of obtaining composite samples.

Since each waste discharge represents an individual situation, the parameters to be measured should be those that can cause a significant deterioration of quality in the receiving medium, or that through biological concentration can cause a hazard to specific organisms in the food web, including man.

In conjunction with the three monitoring systems discussed above, the demand on a resource and on resource usage should be continually monitored. This activity requires little more monitoring than is described previously. The primary activity is the accumulation and maintenance of a usage data base. Aerial surveillance flights can provide some information. However, most of the information concerning demand determinants and use will come from DoD bases and facilities. Examples would include:

- Demographic information--residence, occupation, water and sewer connections, land use
- Economic information--procurement of goods and services requiring use; consumption of power and fuels, products, intermediates, and raw materials; license, fees, and tax records related to resource use; income and spending distributions
- Resource use information--recreation surveys, meteorological data, evaporation rates, industrial water diversion.

Finally, the monitoring program needs a well designed Data Management System to accept, store, edit, and disseminate the data collected by the four systems. Because of the voluminous quantity of data collected in a well designed monitoring system, the DMS will undoubtedly be automated or depend heavily on a computer. The components of a DMS are described in Section IV of this chapter, together with an example of one way in which a DMS can be structured.

CHAPTER EIGHT--DATA MANAGEMENT AND MONITORING

IV--DATA MANAGEMENT SYSTEM

IV THE DATA MANAGEMENT SYSTEM

A. Data Management System Design Considerations

The DMS is a vital tool in the Environmental Data Monitoring Program, and its effectiveness depends on the design of the system, its interfaces, subsidiary data processing locations, and procedures for data handling and transmission. For example, there may be great advantage in having access to remote large data bases or computers via telecommunications. The ARPA network is a likely candidate for a communications capability that would provide interchange of environmental data between several data processing centers. In this case, storage of data could be distributed and the data processing could also be located at separate points. There are cost-effectiveness considerations to be examined under these circumstances, as well as trade-offs that require close study to determine the most promising implementation.

Figure IV-1 shows the relationship of the DMS to the total environmental program.

B. The Data Management System (DMS)

The DMS should be designed in response to the needs and objectives of the DoD. These needs and objectives are related directly to the managerial decisions concerning the level of desired environmental protection.

Some management actions are closely tied to their effects. Therefore, these actions require information feedback on the extent of these effects with a short turnaround time. Other management actions are based on trends in effects. This may be necessitated because of a long delay

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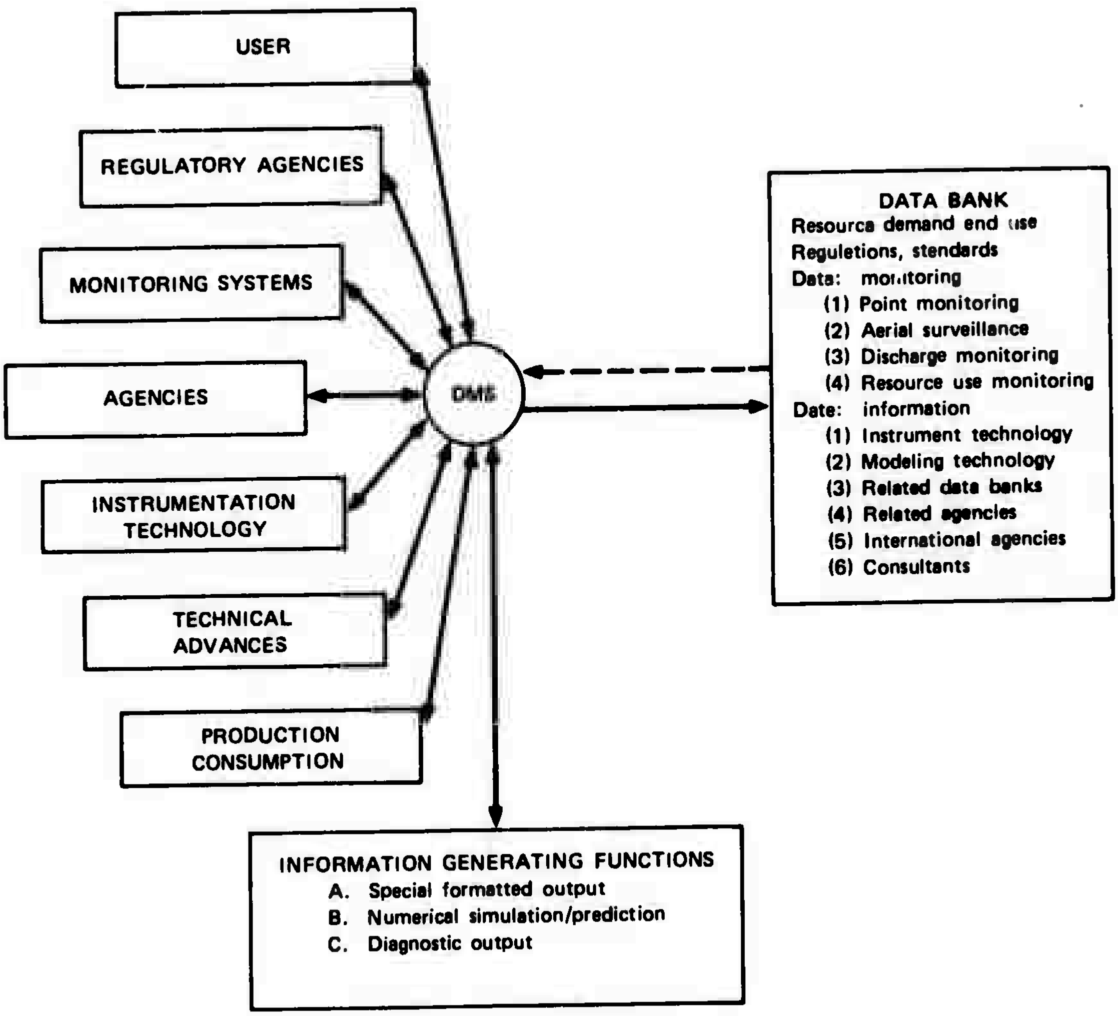

FIGURE IV-1 RELATIONSHIP OF DATA MANAGEMENT SYSTEM TO THE TOTAL ENVIRONMENTAL PROGRAM time or an indirect relationship between action and effect. It may be that the effect is only evident statistically and that the overall direction of the trend becomes apparent only after a time. Therefore, it is necessary that the information system establish a baseline and develop historical trends on certain parameters related to environmental quality.

The management information system will help the DoD to develop effective resource management policy. The information obtained from the monitoring program, together with that available from historical records and controlled laboratory experiments, will enable the DoD to develop an understanding of resource use-effects relationships. This understanding will grow with time, and if it is expressed within a systematic framework, it will provide the capability to make increasingly accurate predictions of the environmental effects of resource use.

Basically, the DMS consists of seven subsystems:

- Input function
- Output function
- Data processor function
- Data bank
- Measurement and collection function
- Accounting and self-auditing function
- Scheduling function

Each of these subsystems can be designed as a separate entity but with the constraints of the total DMS imposed. Since resources will be limited, provision will be made for future expansion in each subsystem. Any of the subsystems may have a human link if the process of automation becomes unjustifiably complicated for the service performed. For example, data may be transferred first to punch cards before being entered into the data bank. Figure IV-2 is a flow chart of the DMS.

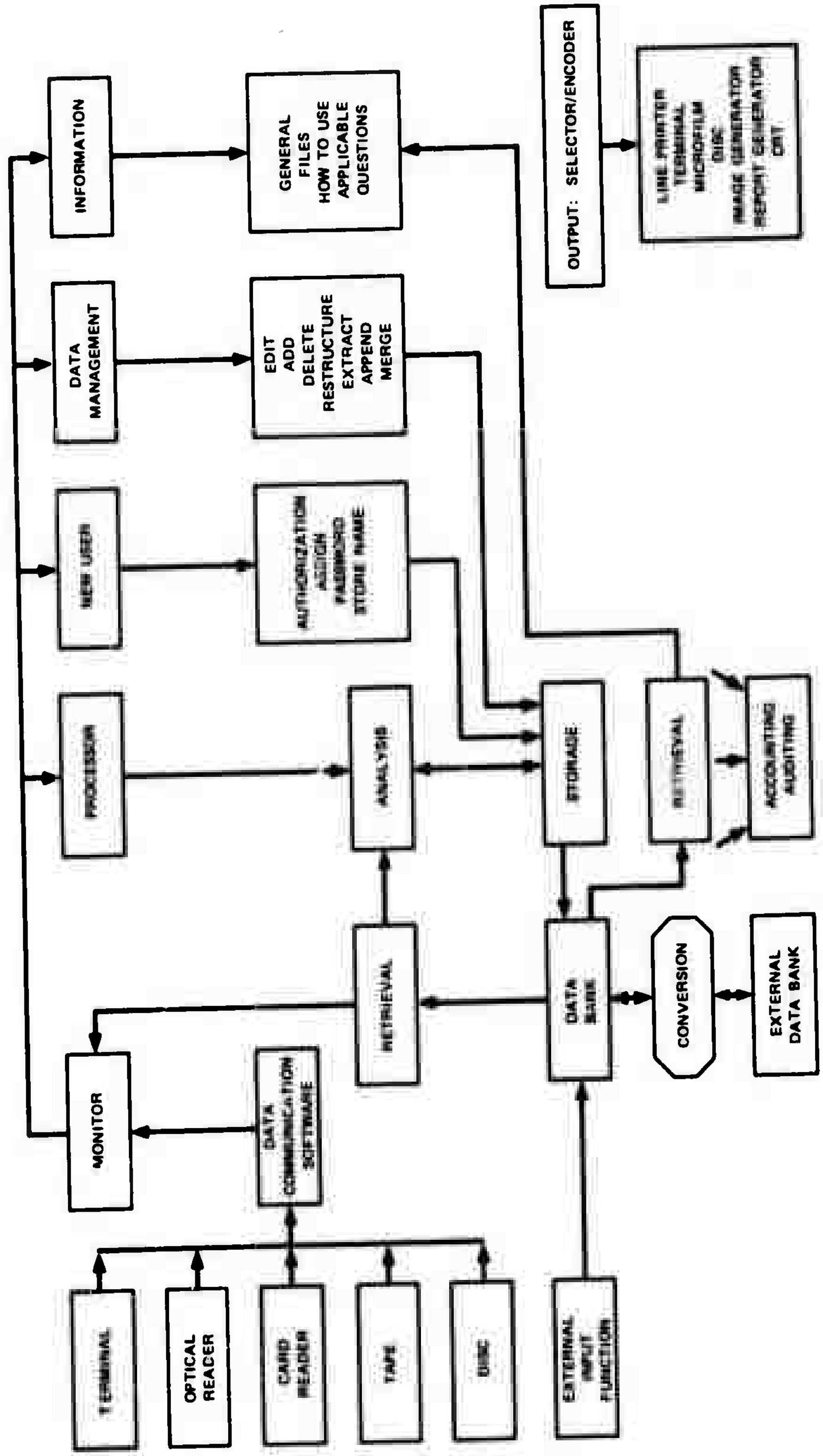

FIGURE IV-2 DATA MANAGEMENT SYSTEM

Technically, the DMS can be designed to accommodate many different input devices by "front-ending" the system with a communication package. In practice, there is the risk that providing service for all the input modes may be unjustifiably expensive; certainly there will be a trade-off between terminal flexibility and cost of implementation.

As in the input subsystem, the display subsystem can become unnecessarily complex if an attempt is made to include all possible output devices. A realistic survey of user needs should be undertaken to establish what hardware devices DoD personnel should use and which ones should be included in the first DMS.

The processor subsystem is most difficult because of the tremendous latitude of possible functions. An executive routine should control the subroutines of the processor, consisting of a minimum of:

- Interrogation subroutine
- Storage subroutine
- Retrieval subroutine
- Processor subroutine
- Display subroutine.

An auxiliary library of processing programs should be resident in the system and accessible through the processor subroutine.

The interrogation subroutine should intercept incoming requests and direct the executive function as to the action required. An examination of previous responses will be made by this routine to determine if the query has been answered previously. Information regarding the use and request can be stored by the routine before control is relinquished to the executive function.

The storage subroutine is responsible for storing data from various sources in the data bank. This routine will be restricted by the type of data manager selected, since the structure of the data bank will be dictated by this subsystem.

The retrieval subroutine will retrieve selected data elements from the data bank. It will be accessible from any processor subroutine requiring data.

The processor subroutine will be a collection of routines that are resident in core or accessible by the executive function. The processor should have the responsibility of checking data, creating information files, executing algorithms, and passing control to the executive program to execute special subroutines or "canned" commercial programs.

The display function should provide the ability to display data and information in a wide range of formats. The formatting can either be predefined or defined at run time, depending on user needs. The display subroutine can communicate with the display subsystem that in turn will communicate with the actual output device.

The data bank is the actual storage media used to hold the data for future use. It may be paper, microfilm, magnetic tape, standard disc, or one of the more exotic automatic storage devices available. A complete set of routines is required to manage the data, admit new data, and purge or update old data. These routines include:

- Add and verify
- Edit, change, and delete
- Data output
- Selected retrieval
- Append subsets to the data bank
- Insert subsets in the data bank
- Data bank information generator
- Data bank duplicator.

The data in the data bank can be rigidly structured or relatively unstructured depending on the imposed user constraints.

The measurement and collection subsystem is the monitoring program discussed earlier. It is included because it is an integral part of the DMS design yielding information on sizing and frequency of data input.

The accounting and self-auditing subsystem is included to allow the system to audit use of the DMS. This subsystem should maintain lists of users, user questions, unanswerable questions, and so forth. Since the role of this subsystem is self-auditing, many of the elaborate functions of management information systems should not be included.

Finally, a general scheduling function should be included in the DMS to aid in passing control from one subsystem to the next. Its function would be similar to the executive function except that its scope would be broader and would include all aspects of the DMS. A good scheduler would be able to queue interrogations received from the input routines and execute them when an opportunity arose without disrupting current system work. It also allows inclusion of new modules as new objectives are formulated to meet changing social and technological goals.

CHAPTER NINE

SPECIAL PROBLEMS

INTRODUCTION

The complexity of the physical environment and diversity of impacts from man's activities is such that it is not possible to consider all important topics under the above categories. Accordingly, this chapter includes a number of separate sections that appear to present special problems whose solutions may lead to new opportunities for improvement of environmental quality.

CHAPTER NINE--SPECIAL PROBLEMS

I--DEVELOPMENT OF INDICES FOR EVALUATION OF DOD STATUS AND TRENDS WITH RESPECT TO ENVIRONMENTAL QUALITY

I DEVELOPMENT OF INDICES FOR EVALUATION OF DOD STATUS AND TRENDS WITH RESPECT TO ENVIRONMENTAL QUALITY

A. Statement of the Problem

As required by Executive Order 11507, the National Environmental Policy Act (NEPA), and other directives, the Department of Defense and other federal agencies have directed considerable effort and resources to activities related to the environment. The general experience within DoD concerning these activities is that, although the efforts and actions have shown a steady improvement with time, much still remains to be done to comply with the numerous regulations, standards, statutory requirements, and other issues related to environmental quality. To this end, there is a continuing need for program review, planning, and development of methodologies that will provide for systematic and uniform responses to program actions leading to environmental effects. It is apparent that increasing attention will have to be devoted to translating environmental activity of the DoD into measures that are consistent with evolving procedures promulgated by local, state, and federal agencies charged with evaluating and regulating environmental quality. These agencies are attempting to improve communication of information on environmental trends to policymakers and the general public by means of indices. For this purpose, an index can take many forms, but in general is characterized by an attempt to express the status of a particular problem in numerical terms. At the present time, indices for air quality are the most advanced, but considerable effort is in progress to develop additional indices for water, noise, and other media.

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It would appear appropriate at the present time for DoD to initiate study of environmental indices, with particular attention during the first phase to measures of air quality. In this endeavor the objective should include both an evaluation of the technical base on which the indices are formulated and an assessment and understanding of how they may be used in the future with reference to DoD activities. Given this understanding, the DoD in principle should be in a favorable position to structure its pollution control and data gathering activities in improved coordination with national environmental quality policy.

B. State of the Art

Current progress toward development of environmental indices are summarized in the third annual report of the Council on Environmental Quality. The Council has studied and reported on developing indices in the context of several aspects of environmental quality: air pollution, water pollution, pesticides, land use, wildlife, and toxic substances. In general, although indices for air pollution are more advanced than in the other environmental areas, all are unsatisfactory in some respects and few have been adequately tested to determine their validity. Nevertheless, the Council has encouraged continuing effort toward the development of satisfactory indices of environmental quality. The Council has assembled a preliminary check list of environmental parameters and during the next year will both refine the list and attempt to develop indices for the major categories which comprise 24 indicators of:

- Underlying factors (population, economic development, urbanization)
- Resources
- Ecological factors
- Pollution
- Man-made environment (e.g., housing, transportation)

A goal for federal agencies would be to evaluate the application of pertinent indices related to environmental impacts caused by their operations, and then to accumulate the data necessary to monitor their progress toward improved operations. At the present time, for example, air pollution is reported as follows:

4.1 Air.

4.1.1 Amount of emissions, by type and source (major pollutants: SO_2, CO, oxidants, NO_2, hydrocarbons, suspended particulates).

4.1.2 Percent population exposed to levels above primary standards (health index).

4.2.3 Ambient air quality (index of ambient levels for each major pollutant and composite index for all pollutants).

To show trends in actual air quality, several indices have been used--the MAQI (Mitre Air Quality Index), the EVI (Extreme Value Index), and the ORAQI (Oak Ridge Air Quality Index). The MAQI combines indices for individual pollutants with those relating measured levels of pollution to the national secondary air quality standards promulgated by the Environmental Protection Agency. As implied by the name, the EVI measures the extent of very high-level pollution for short periods of time. The ORAQI is based on EPA secondary standards and is mathematically adjusted so that a value of 10 represents essentially unpolluted air, and a value of 100 represents all pollutant concentrations reaching the federally established standards. These air pollution indices are artificial in certain respects. On the whole, however, they may be useful to the public and to the policymaker in providing an integrated look at the gross status of environmental quality to aid in assessments of current problems, whether control programs are succeeding, and what aspects of the problem are changing and require special attention.

C. Present Activities and Organizations

As noted earlier, the current stage of development and activity concerning environmental indices has been summarized by the recent third annual report of the Council on Environmental Quality. The Council itself and the Environmental Protection Agency lead the activity, which is supported in one way or another by an extremely wide array of federal, state, and local agencies, educational institutions, and research organizations. For the most part, the actual development of indices is restricted to in-house activities and a relatively few contractor organizations working with the Council and EPA; however, if one adds the organizations, monitoring networks, and other information gathering activities that contribute in one way or another, then the sum total could conceivably include nearly every organized activity concerned with or related to environmental quality problems.

D. Implications for DoD

By Executive Order 11514 of 5 March 1970, federal agencies are required not only to initiate measures to direct their policies, plans, and programs to meet national environmental goals but also to monitor, evaluate, and control their activities for the protection and enhancement of environmental quality. To comply with this Order, it is necessary to evaluate and measure total impact on the environment and to assess progress toward established quality goals. Such requirements are expected to become more important in the future. In effect, the progress of government agencies toward control of environmental pollution will need to be stated in more relevant and quantitative measures than the current and traditional summary of dollars expended and facilities constructed. The Congress and the public will expect the DoD and other agencies to establish standards for impacts in several media, and then to describe methods and approaches for meeting the standards within stated times. Of concern to

EPA at present are air, water, radiation, pesticides, solid waste, oil, and hazardous materials. To meet national requirements for such information, DoD will need to initiate development of an understanding of appropriate indices and indicators of environmental quality and the data needed for measurement of the indices. Therefore, this problem area implies consideration of not only the standards that must be met and the criteria and objectives needed to formulate the standards but also the monitoring techniques that will be required to provide the necessary data.

E. Recommendations for Future Studies

Following the development of an appropriate understanding of DoD requirements with respect to indices for air quality, it would be necessary to extend the experience gained to similar efforts for water, radiation, pesticides, solid waste, oil, and hazardous materials. The initial effort toward air quality should provide a suitable background for framing and organizing the procedures, and it would be reasonable to assume that work could proceed simultaneously on most of the additional media, with emphasis on those for which the indices are most advanced. These would be selected from the major categories of the CEQ preliminary checklist of environmental parameters. A summary of these is presented below by the two-digit numbers under the five broad parameters.

1. Underlying factors
    - 1.1 Population
    - 1.2 Economic development
    - 1.3 Urbanization
2. Resources
    - 2.1 Supply and demand--renewable resources
    - 2.2 Supply and demand--nonrenewable resources (United States and world)
    - 2.3 Land
    - 2.4 Food
    - 2.5 Solid waste and recycling
    - 2.6 Energy

3. Ecological factors

   3.1 Climate
   3.2 Natural disasters
   3.3 Wildlife
   3.4 Maintenance of major ecocycles

4. Pollution

   4.1 Air
   4.2 Water
   4.3 Radiation
   4.4 Pesticides
   4.5 Noise
   4.6 Toxic substances

5. Man-made Environment

   5.1 Housing
   5.2 Transportation
   5.3 Aesthetics
   5.4 Occupational environment
   5.5 Recreation

CHAPTER NINE--SPECIAL PROBLEMS

II--TOTAL ENVIRONMENTAL INTERACTION ASSESSMENT

II TOTAL ENVIRONMENTAL INTERACTION ASSESSMENT

A. Introduction

Increased DoD environmental protection planning in accordance with Executive Orders 11507 and 11515 is leading to a requirement for thorough understanding of the interaction between defense activities and the total natural environment. Such understanding is necessary to ensure that the limited resources available for defense environmental protection will most effectively curb adverse environmental change without causing unnecessary reduction of defense capability.

In considering environmental protection steps for an activity, it is not likely that separately derived measures for decreasing depletion of scarce resources or reducing pollution of air, water, or land will be as effective overall as measures derived by considering the activity-environment interaction as a single system. It is often the case, for example, that water pollution control steps can lead both to increased air pollution and increased power consumption. Unless both the latter factors are considered as part of the system, a satisfactory balance between the various adverse environmental effects may not be reached or excessive reduction in operational capability may occur. It appears advisable, then, to find methods to assess simultaneously the multiple effects of an activity on multiple components of the natural environment and the effects of environmental change on the activity.

B. Background

Much effort is under way on assessing the effects of single activity processes on single environmental components, and part of the converse--

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the effect of resource availability on activities--has long been studied under logistic contingency plans. However, to establish priorities for control of process effects on environmental resources, the further effect of resource changes on other resource users must be known and much of this information is not yet available. In addition, relatively little study, especially with empirical data, has been made of the simultaneous effects of multiple processes on multiple environmental components.

Even though study of simple activity-resource interactions has been going on for some time, significant gaps in knowledge remain, and since models from these investigations will become submodels in a total interaction study, it is probable that the state of the art in environmental analyses is not now sufficient to produce a reliable predictive analysis of a total interaction. The recourse is to monitor data to examine the correlation between activity actions and environmental effects. The data can be organized according to an overall activity-environment interaction model concept, and, where feasible, submodels of established validity may be used to enhance understanding of the mechanisms of the interaction.

SRI has derived an overall activity-environment interaction model concept based on a dynamic multiloop nonlinear feedback characterization developed at MIT but viewed on a scale that enables use of empirical inputs. The concept should be helpful in organizing and correlating monitoring data from activity input, operation, and output events and in connecting independently derived models of specific consumption and pollution processes.

C. Method of Approach

1. Statement of the Problem

To minimize adverse environmental effects from defense activities while maintaining required defense capability within available funding and manpower constraints will require good understanding of the interactions of defense activities with the totality of the natural environment. Since activity resource depletion and air, water, and land pollution do not occur independently, environmental protection measures must be designed with the interactions in mind.

To gain the necessary understanding, resource input, activity operation, and waste output flows from defense activities must be efficiently monitored and, to the degree possible, analyzed to learn the sensitivities of both activity and environment to changes in operating conditions. Environmental protection control measures should result that efficiently decrease adverse environmental effects while minimizing operational capability degradation.

2. Study Plan

Tasks necessary to develop a plan to assess the interaction of defense activities with the environment could be to:

- Select one or more DoD installations or operations for pilot examination. The activities should contain one or more processes with significant interaction with the environment and preferably be relatively isolated from other activities with similar environmental effects. If possible, activities with existing environmental monitoring programs should be chosen.
- Make an inventory of the activity processes with significant resource consumption or waste emission characteristics and assess the state of both the resource input recording procedures and the emission monitoring program. Achieveable improvements in both input and output monitoring should be determined as should measures for activity operational effectiveness and an assessment made of the effectiveness of the monitoring capability.
- Determine appropriate data storage and retrieval procedures.

- Determine the sensitivity of activity operational performance to changes in resource input quantity or quality. Assessment of the effect on operations of candidate environmental protection measures, both singly and in combination, should begin.

- Determine the principal other resource users affected by the activity impact on the environment. Numerous similar small users may be aggregated into user classes. This task includes evaluation of the availability of models or state of knowledge of the effect on these other users of resource depletion or pollution. Significantly affected other users would also be considered even if not located near the activity.

- Collect and evaluate relevant air and water quality models to determine their suitability for inclusion in a comprehensive, empirical-input, activity-environment interaction model. Specifically, validity assessments should be checked with real world data.

- Using an overall interaction model concept as a guide, determine combinations of data correlation and proven submodel use that relate resource inputs with product and by-product outputs and give insight into the sensitivity of both activity and environment to changes in activity operation or resource characteristics.

- Assess the overall effects of various combinations of environmental protection measures, including activity operation schedule management, on the environment, on other resource users, and on the activity itself.

- Identify a spectrum of environmental protection measure combinations that provide a gradation in environmental protection effectiveness.

CHAPTER NINE--SPECIAL PROBLEMS

III--DEVELOPMENT OF TWO-WAY VIDEO COMMUNICATION SYSTEMS--IMPLICATIONS FOR RESOURCE DEMAND AND ENVIRONMENTAL QUALITY

III DEVELOPMENT OF TWO-WAY VIDEO COMMUNICATION SYSTEMS-- IMPLICATIONS FOR RESOURCE DEMAND AND ENVIRONMENTAL QUALITY

A. Statement of the Problem

In any complex organization, the need to exchange material and information leads inevitably to the establishment of communication and transportation systems for both internal and external use. While communication and transportation complement each other, recent advances in telecommunications and changes in operational procedures have increased the potential for communications to substitute for transportation. Planned substitution of communication for transportation can lead to environmental improvement and reduced fuel and materials requirements. To be effective, this substitution requires early and careful planning.

Clearly, some exchanges simply cannot be achieved by telecommunications. These inevitably include hard physical goods. However, information exchange, which is an ever-growing fraction of all transactions, is highly susceptible to substitution of communications for transportation. In the near future, substitution for personal interactions now accomplished by contact will be limited more by habit and by psychological, sociological, and economic constraints than by technological shortcomings in available two-way audio-video communication equipment.

In the past, communications and transportation have been considered and planned separately, this practice often being made difficult by the establishment of separate offices and responsibilities. Advances in telecommunications are making that practice obsolete, and planning for land use, transportation, and communications needs to be coordinated as never before to enable full realization of opportunities posed by modern technology.[1]

B. State of the Art

Remote input/output terminals for computer timesharing have become common, appearing in banks, licensing bureaus, police stations, to name just a few. Most of these terminals are little more than teletypewriters connected to the computer over common or leased telephone lines. Considerably more sophisticated, but less common, are terminals with a video as well as typed output with advanced facilities such as light pens to enable man-computer interaction. For many applications, the user can be satisfied with the video output and never require production of paper copy.

Portable, remote facsimile, also using common telephone lines, is another use of telecommunications that is becoming more common (about 50,000 in use in the United States). At the present, these devices require four to six minutes to transmit an entire 8-1/2 X 11-inch typed page. Nevertheless, these devices are finding use in businesses as a substitute for mail for high priority items, for interactive conversations concerning graphical material (albeit at a somewhat slowed pace), and for relatively rapid submission of textual information from field locations such as by news reporters and sales personnel.

There are now means of achieving video, face-to-face, personal telecommunication on a random access basis. One method, called "slow scan," uses a combination of common telephone lines, standard industrial television cameras and receivers, a "frame-grabber," and a scan-converter to

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[1]E. M. Dickson and R. Bowers, "Video Telephones: A Technology Assessment," Program on Science, Technology and Society, Cornell University, Ithaca, New York. In preparation.

freeze an image and then to translate the transmission of video information from the usual television rate of 525 lines per frame, 30 frames per second (which requires a 4 MHz bandwidth) downward to the 3 to 4 kHz bandwidth of common telephone lines. A memory device is required to store and reassemble the transmitted image. Only about one image can be transmitted every minute, making the technique relatively uninteresting for face-to-face conversations but useful for discussions concerning graphical or textual material. The effect is similar to a slide show. At present, resolution is barely, but not comfortably, adequate for textual material with typefaces in current usage.

In contrast to the slow-scan system which presents a "slide show," an animated effect is presented by the Picturephone® of the Bell system, the Bell-compatible Vistaphone™ of Stromberg-Carlson, and similar instruments of several foreign telecommunications suppliers.*

The Bell Picturephone[2,3] uses a 1 MHz bandwidth and is capable of providing 30 frames per second consisting of 250 lines, each containing 257 picture elements. This resolution is about one-fourth that of standard broadcast television. The signal can be transmitted from the terminal (which includes a camera and a 5-1/2 x 5-inch display in a single desk-top instrument) in analog form by three "conditioned" sets of ordinary telephone lines for a distance of about six miles (one pair for each direction of video, one pair for the audio). For distances beyond six miles, the signal is digitally encoded.

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* Siemens, Ericcson, Plessey, Fujitsu, Nippon Electric, Toshiba.

[2] Bell Laboratories Record, No. 47, 134-187, entire issue (May/June 1969).

[3] Bell System Technical Journal, No. 50, 219-709, entire issue (February 1971).

Because of the animation, video telephones give an added dimension to human conversation, as well as provide a means of interactive discussions using textual or graphical material. Additionally, they can serve as a remote computer terminal by using either a push button "dial" or a full keyboard. Although none is yet commercially available, straightforward use of the 1 MHz bandwidth would also enable rapid (about 1 second) remote facsimile. In its present configuration, the Picturephone does not have adequate resolution to deal comfortably with textual material using type faces currently popular. However, it is apparent from commercial trials that user interest warrants rapid improvements in resolution and development of complementary devices to facilitate the textual and graphical uses. The technology in transmission, logic, and storage required for these improvements is changing very rapidly.

Within the next five years, planners should begin to take cognizance of the relationship between video telephone technology (and its complements) and transportation. The video telephone terminal and system will be capable of random access animated video sufficient for face-to-face communication, a higher resolution high speed mode providing good textual and graphical transmission, a facsimile attachment capable of memorializing this quality in paper copy, and a full keyboard facilitating computer access. It is less certain, but color may be available at about the same time. While the system described will be neither ubiquitous nor inexpensive, it will certainly be available for internal communications systems with some access to the external world.

C. Present Activities and Organizations

Bell's present generation of Picturephone is commercially available on an exchange basis in Chicago and Pittsburgh. On an intercom basis, such video telephones can be made available almost anywhere. At this time, perhaps 1000 Picturephones are in operation. Fewer slow-scan systems are installed, but since these use the ubiquitous common telephone line they are likely to become more common.

Around the country, there are various trials of two-way video techniques which approximate video telephones. One of the most active areas of interest is in the medical context; the Health Care Technology Division of the Health Services and Mental Health Administration of HEW is sponsoring contract research testing the usefulness and adequacy of video telephone systems in health care. Other geographically dispersed organizations are implementing systems resembling an internal video telephone system, among them the Port of New York Authority. Still other organizations have implemented video conferencing arrangements, notably the NASA Apollo project. Alcoa has developed and is marketing a computer data information software package for use with the Picturephone.

D. Implications for DoD

Most environmentally related benefits accrue from reduced need to physically travel and, as a consequence, reduced fuel and resource depletion and new opportunities for land use planning. The net energy savings can be far from trivial. For example, a round trip transcontinental trip from New York City to Los Angeles on a Boeing 747 aircraft[4] at normal load factors for the purpose of accomplishing eight hours of personal contact consumes several thousand times as much energy as would be expended on an eight-hour transcontinental video telephone conversation. The energy contained in a single gallon of gasoline is sufficient to provide either about a 15-mile journey by automobile or 80 hours of video telephone connection at a six-mile distance. In addition, there

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[4]As operated by American Airlines in the first quarter of 1972. Aviation Week and Space Technology, No. 97, p. 40-41 (31 July 1972).

may be significant national energy savings by lessening the demand for objects that have a large intrinsic energy content such as aircraft and land vehicles.

The DoD, a large and dynamic organization, could profitably use emerging video telephone technology to enhance communications between and within installations. If planned as a substitute for transportation, the following benefits could accrue:

- Decrease in number of vehicles required, resulting in less noise, pollution, materials resource depletion, fuel consumption and waste disposal attendant with vehicle operation, maintenance, and roadway repair.
- Increased efficiency of personnel by the reduction of time lost in travel and an attendant increased effectiveness in space heating because of a higher occupancy rate of buildings.
- Increased ability to put training activities on a CAI (computer aided instruction) basis from either local or remote computers, thereby reducing space, heating, and transportation requirements.
- Increased flexibility in land use planning, since operations whose major exchange is information (rather than material) no longer need to be in close physical proximity. Similarly, noxious or dangerous activities can be located at more remote locations while maintaining strong communications links.
- Ability to provide personnel separated from their families with a more "personal" communication link, perhaps reducing need for providing transportation for visits while still maintaining morale.

E. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Determine, by function, which activities concerning transportation would be susceptible to substitution by video communication.

- Determine the energy savings if the relevant substitutions were made.
- Determine the changes in installation land use that could be facilitated.

CHAPTER NINE--SPECIAL PROBLEMS

IV--COMBAT TRAINING ELECTRONIC SIMULATION

IV COMBAT TRAINING ELECTRONIC SIMULATION

A. Statement of the Problem

The development and maintenance of expertise through rigorous training programs to establish a combat ready posture is one of the principal occupations of the armed forces. Because of the enormous logistic support required for modern warfare, actual combat training is only a fraction of the total. However, training for combat tends to have a more markedly destructive impact on the environment than training required for support services. Combat training consumes prodigious quantities of physical resources in the form of materials and fossil fuels, and it is often extremely noisy and adversely affects large tracts of land--especially where bombardment exercises are concerned. A significant number of the concerns discussed elsewhere in this document are found to an aggravated degree in realistic combat training. This fact often is a determinant in the selection of the geographical location of a facility.

Since it is easier to maintain expertise than to develop it, the trend toward all volunteer armed forces could have a favorable impact on the environment; as personnel remain with the service for a longer time and the need to train fresh recruits diminishes, the greater consumption of resources associated with skill development also will diminish. Completely consonant with an increased professionalization of the armed forces would be a move to substitute sophisticated electronic simulation training exercises in the field. Present electronic simulation technology is potentially a more powerful and more rapid method of developing expertise than present methods. Movement by DoD in this direction would carry significant environmental and other benefits.

B. State of the Art

Electronic simulation complete with audiovisual effects is very advanced in some fields such as training for commercial airline pilots and astronauts and some training for air traffic controllers. The successful simulations are those that judiciously examine the components of the exercise for which realism is essential and those for which it is not essential and that reflect these evaluations in the simulation programs. Often substantial computing capacity is required for real time simulations; however, since the data rate is rather low, the simulator and the computer can be connected even by long distance telecommunications.

An electronic simulation of an exercise need not be less realistic than present exercises that are also simulations of actual combat. Indeed, with thought in construction of the simulation program, the electronic exercise can be made more rigorous than present field exercises by combining effects that are difficult to arrange in the field where terrain and weather combinations fail to provide the desired range of effects. It is not possible to maintain an inventory of exercise locations in all the varied terrain that it would be possible for a computer to imitate. Furthermore, rigor can be increased by simulating and varying an enemy response that is simply not present in many of the training exercises currently used.

One advantage of simulated exercises is the ability to change the computer program to reflect modifications and changed performance in actual hardware in anticipation of the actual delivery of the new hardware, thus smoothing transitions between hardware types and ensuring continued readiness. Another advantage of electronic simulation is the ability to stage emergency actions stemming from equipment malfunction without actually endangering personnel or materials and to do this repetitively.

C. Present Activities and Organizations

Three of the environmental impact statements received for consideration in this report (Appendix A) will illustrate the concept of simulation substitutions for environmental improvement. The Department of the Navy EIS on the "Use of Target Ship Hulls in Exercises at Sea" (Reference AR-34) describes the use of obsolete, stripped down, ship hulls to provide realistic targets during combat readiness evaluation exercises. Since the total consumption of these hulls is only about 15 per year, these evaluations presumably are the infrequent culmination and coordination of substantial individual and smaller group training exercises of the kind described in two Department of the Navy EIS's, "Relocation of Target Facilities from Aqua Cay to Cross Cay Atlantic Fleet Weapons Range, Puerto Rico" (Reference AR-40), and "Kahoolawe Island Target Complex, Hawaiian Archipelago" (Reference AR-38). These two statements describe uses of islands as target ranges for ship and aircraft bombardment. In both, targets are marked out on the ground for practice bombardment; on some occasions obsolete vehicles are used as targets. All these activities on islands are themselves simulations, since the terrain remains constant from exercise to exercise, the weather conditions are generally good, the targets are not real and are often only marks on the ground or natural rock structures, and above all the targets do not take evasive action or retaliate. (See Table IV-1.) Nevertheless, the Kahoolawe Island EIS considers that these provide "combat realism" in a "realistic environment" (AR-38, p. 25).

Apparently, a higher level of realism is judged to derive from the bombardment of the ship hulls, no doubt because the target profiles are more appropriate and the complex internal structure of a ship that plays a role in its susceptibility to damage by bombardment is not imitated in the island targets. No doubt also there is a psychological benefit to the players in the exercise to see the ship sustain damage and eventually

Table IV-1

KAHOOLAWE ISLAND TARGET COMPLEX, HAWAIIAN ARCHIPELAGO
(Department of the Navy Environmental Impact Statement AR-38)

The training of aviators and surface units in the art of air-to-surface and surface-to-surface weapons delivery must be conducted in a realistic environment that simulates actual combat conditions as closely as possible to achieve the most positive transfer of learned responses to a combat situation. Combat realism is obtained by diversity in types of targets within a target complex, such as:

(1) Area targets, e.g. runways, simulated industrial complexes.

(2) Point targets, e.g. simulated surface-to-air missile sites, revetments, bunkers, storage tanks, trucks.

(3) Targets of opportunity, such as truck convoys.

(4) Open and easily spotted targets.

(5) Targets hidden by terrain features or foliage.

(6) Reverse slope targets, i.e. targets located on the rear of an intervening ridge or hill (especially necessary for Naval gunnery exercises).

(7) Varying terrain features that are useful for training in night operations, target orientation, and acquisition and complete testing of the aircraft ordnance release system.

[At Kahoolawe] a total of 17 air-to-surface and 21 surface-to-surface targets have been constructed. A compilation of the nature of the target and the ordnance authorized for use on each target includes:

(1) Air-to-Surface Targets:

A-1 Rock Ring, 25 feet---Up to a 500 lb bomb
A-2 Rock Ring, 25 feet---Up to a 500 lb bomb
A-3 Rock Ring, 25 feet---Up to a 500 lb bomb
A-4 Rock Ring, 25 feet---100 ft, 500 ft, 1000 ft (loft bombing target; inert ordnance)
A-5 West Airfield--------Up to 500 lb bomb
A-6 Antiaircraft site----Up to 500 lb bomb
A-7 Complex target, 10' bull, 40', 100', 200', 300' ring--------------Inert ordnance

A-8 No. 1 strafing target - 20 MM
A-9 No. 2 strafing target - 20 MM
A-10 MK-76/2.75 FFARTGT
10' bull, 100', 200', 300' ring (practice only)
A-11 Rock Ring, 25'------Up to 500 lb bomb
A-12 "Walleye" target----"Walleye"
A-13 ("Z" Convoy) West
Convoy------------------Up to 500 lb bomb
A-14 Central Convoy------Up to 500 lb bomb
A-15 East Convoy---------Up to 500 lb bomb
A-16 East Airfield-------Up to 500 lb bomb
A-17 Surface-to-air
missile site-----------Up to 500 lb bomb.

(2) Surface-to-Surface Targets

S-1---------Natural rock target at shoreline
S-2---------Natural rock target at shoreline
S-3---------White Cliff target at shoreline
S-4---------Rock pyramid target 6' X 6' X 6' high
S-5---------Barrel pyramid target 7' X 7' X 11' high
S-6---------Rock pyramid target 6' X 6' X 6' high
S-7---------Rock pyramid target 6' X 6' X 6' high
S-8---------Drop tank (night illumination target)
S-9---------Drop tank (night illumination target)
S-10--------Truck target (night illumination target)
S-11--------West end truck convoy
S-12--------East end truck convoy
S-13--------Rock Ring target, 25' (reverse slope ring target)
S-14--------Rock Ring target, 25' (reverse slope ring target)
S-15--------Rock Ring target, 10', 25'
S-16--------Truck Target
S-17--------Truck Target
S-18--------Rock Pyramid 12' X 12' X 8' high
S-19--------500 yd X 600 yd targets
S-20--------Barrel pyramid target
S-21--------Friendly Village.

During the period from 1 January 1970 to 30 June 1971, Kahoolawe Island was visited 547 times--an approximate average of once every day.

sink. Nevertheless this realism is compromised by the lack of evasion or retaliation on the part of the hulls, and even if enemy air defense of the targets is imitated, there is little actual physical danger to the offensive forces. Consequently, these activities themselves are very much simulations of warfare.

Very little attention seems to have been devoted to consideration of the substitution of electronic or other simulations for the bombardment of the islands. The Kahoolawe Island EIS raises the following points:

(1) Live (nonnuclear) bombing ordnance provides experience to handlers and fusers as well as pilots.

(2) A complete practice bomb should have the same weight, construction, and fusing capability as the real bomb, as well as an explosive charge sufficient to release smoke for visual spotting and evaluation of delivery performance (the implication is that such bombs are not available).

(3) Reverse slope targets (those on the rear slope of an intervening hill or ridge) are especially needed for Naval gunnery exercises.

(4) No-ordnance bombing exercises could be conducted at the Pacific Missile Range Facility, Barking Sands, using procedures similar to aerial mine laying exercises; electronic scoring is possible by equipment already (1970) installed at the facility.

However, "although some training benefit might be derived by use of such a system, it is not considered to be an acceptable alternative to the use of Kahoolawe Island."

These points make it clear that evaluations of the quality of present physical simulation methods relative to the potentials of electronic simulation are not generally performed and are further constrained by unsustainable conventional wisdom about simulated training activities. The following are comments point by point on the above observations.

(1) Practice in the handling and fusing of bombs need not lead inevitably to the delivery of the bomb. Exercises with live ordnance could end with the attachment to a dummy aircraft (and then removed and deactivated).

(2) Computer simulation could imitate not only the specific bomb characteristics but also the pilot's cockpit, the terrain, and the weather and provide probabilistic hit or miss information based on the pilot's manipulation of his controls. Thus not only is a practice bomb in the form described not needed but neither is the aircraft or the target. Visual display with appropriate audio effects could be provided.

(3) Reverse slope bombardment is an exercise ideally suited to computer simulation, since in actual situations the visual feedback to the gunnery crews is very meager. Computer simulation can pose problems to gunnery crews with specified weather and terrain characteristics; and, based on inclination settings and the like of the guns can yield a probabilistic evaluation of hit or miss performance. Not only need the ship not sail to the practice site, but the ship need not sail at all, and, indeed, land based practice guns could do as well as a ship.

(4) An intermediate level of electronic simulation of combat bombing would require actual passes by an aircraft that did not entail the release of ordnance of any kind, but involved computer evaluations of the probability of a hit or miss based on the terrain, weather, and flight parameters of the aircraft at the instant the simulated release was triggered. In the case of laser guided "smart" bomb practice, an optical sensor on the ground serving as the target could evaluate the manipulation of the laser guide beam without release of ordnance. Even this, however, could be fully simulated. In all these cases, the operation no longer would be geographically constrained to target complexes.

D. Implications for DoD

Increased use of electronic simulation techniques might easily cost as much (and, initially, perhaps more) than field simulations in dollar terms; but in materials, fuel consumption, and environmental quality terms, the cost is certainly less. The impacts on air and water quality and noise levels would also be especially improved. Ancillary benefits would include the decreased dependence on favorable meteorological conditions to enable the training activity and less constraint on geographical location of the activity, and the ability to couple the simulation with distant computers would enable refresher training without journey to a special training center. The attendant increase in overall efficiency of DoD in its training activities would surely have favorable implications for resource consumption.

There must be some final coordinated, realistic field training at the end of the simulated training, but the quantity of this training is probably amenable to significant reduction in scope and detail when preceded by simulation training. For the activities that must remain as field exercises, it would be beneficial to integrate into the administration of training scheduling the meteorological and air quality data necessary to minimize air pollution contributions as well as to avoid conditions with adverse noise propagation characteristics. Also, it should be relatively easy to evaluate scheduling practices to avoid concentrations of noisy activity and to spread it more uniformly during hours and days during which nearby nonparticipative populations (both military and civilian) are least sensitive.

The basic implications for DoD of increased use of electronic and computer simulation of combat training are summarized below. Increased use of electronic simulation techniques offers potential to:

- Greatly reduce expenditure of materials and fuels.
- Greatly reduce noise and hazards to populations and troops.
- Extend the useful lifetime of target complexes by reduced utilization.
- Reduce dependence on a few remote geographical locations for exercises.

- Deactivate some target areas and return to civilian use.
- Improve the efficiency and rigor of training while achieving all the environmentally related advantages.

An important limitation of this approach would be the need to revise present institutional aspects of the training process.

E. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Review the state of art for training simulations.
- Reevaluate training exercises with a view to determining which are amenable to electronic simulation.
- Examine the savings in materials and fuels that simulation of training would provide.
- Examine the amount of air, noise, and water pollution reductions that could be achieved.
- Evaluate the need to maintain the present inventory of target complexes and alternative uses for the sites.
- Assess the procedural and institutional changes required to fully use simulations as an important part of combat training exercises.

CHAPTER NINE--SPECIAL PROBLEMS

V--EFFECTS OF RADIO FREQUENCY RADIATION ON THE ENVIRONMENT

V EFFECTS OF RADIO FREQUENCY RADIATION ON THE ENVIRONMENT

A. Statement of the Problem

The many agencies of the Department of Defense operate a very large number of transmitters over wide bands of frequency and power. Concurrent with this in the civilian sector, the low cost of modern electrical circuits has resulted in a great increase in the use of electronic equipment in homes and industry. Thus, the possibility that these circuits would be interferred with or damaged by radiation from DoD-controlled transmitters is monotonically increasing. Recently, concern has also mounted that these same radiators may have harmful effects on biological species, including man. The Soviets and the Japanese have also shown concern about the effects of low-level microwave radiation on man, and much Russian literature reflects this concern.[1] Possible effects of microwave radiation on thinking ability was even mentioned in conjunction with the Spassky-Fischer chess match.[2] This new issue is extremely complex, and the nature of possible effects is poorly understood.

B. State of the Art

Military equipment is reasonably well protected against interference or damage from external radiation, since the equipment must meet radio frequency interference (RFI) specifications [also called electromagnetic interference (EMI) specification]. All military electronic equipment must meet EMI specifications both for protecting the equipment from outside

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[1] "Current Status--Electronic Pollution and Management and Measurement," H. Dean McKay, Fairchild Electro-Metrics Corp., 1970 IEEE Regional EMC Symposium Record, San Antonio, Texas (October 1970).

[2] "Fischer-Spassky Charges: What Did the Russians Have in Mind?" Science, Vol. 177, page 778 (September 1972).

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transmitters and for preventing unwanted radiation from the equipment into neighboring installations. However, consumer, commercial, and industrial equipment often does not incorporate special precautions against EMI, although there are certain FCC limits on the amount of power such equipment can radiate in specified frequency bands.

Three general levels of interference can be expected. They are:

(1) Occasional low-level events that cause no damage and are primarily a nuisance.

(2) Larger amplitude or more frequent occurrences where systems are rendered inoperable when the interference is in progress.

(3) Radiation so intense that permanent damage occurs to semiconductors, transistors, or other components in the exposed equipment.

Occasional events or "spooks" (Class 1 above) are difficult to trace because they occur infrequently and therefore are difficult to assign to a particular activity. Some of these events, because they occur at low rates, may actually be caused by equipment malfunction rather than interference. This kind of interference is of minor importance, because it has little economic effect and is difficult to trace.

Higher level interference (Class 2 above) is probably the most serious offender and does have important economic effects. Since events of this kind are relatively easy to trace if they are continuous, the DoD activity causing the interference is often easy to identify.

The last of the classes above is believed to have low probability of occurrence since it requires that sensitive equipment be exposed to high levels of radiation. The economic effects could be very large, since permanent damage occurs and the damaged equipment is out of service completely until replacement units are installed.

The signal strengths likely to cause noticeable effects in each class or level of interference can be calculated. In general, radio communication networks are the most sensitive to interference, but the expanded use of digital data terminals for a wide variety of applications makes the exposure of digital systems greater on a numerical basis.

The present state of the art in predicting nonionizing radio frequency damage to biological species is relatively primitive. This situation is not likely to be relieved soon since many of the effects (if any) may be quite subtle. The effects of high power level/short exposures have been determined relatively easily. Although initially considered harmless, as a result of research and some field incidents the military has established effective guidelines for protecting personnel who must work in proximity to such equipment.[3] Much less information exists on the effect of long term low level radiation. The effects may not be directly harmful, but species may simply avoid the area of radiating installations. Otherwise harmless radiation levels have an effect (not necessarily serious) on heart pacers.[4] The effects on human prosthetic implants such as metal pins, plates, and meshes and long term power absorption and heat stress are not yet known, although the early results are encouraging. Exposure criteria for frequencies below 300 MHz exist but are not well established.[3]

C. Present Activities and Organizations

The Federal Communications Commission (FCC) is the most visible agency; it assigns non-DoD frequency allocations and sets the limits on maximum radiated power permissible in various activities. The FCC has authority to act on radiation that is affecting radio communications networks but has no authority on nonradio systems.

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[3] "Control of Hazards to Health from Microwave Radiation," U.S. Air Force Manual, pp. 161-7.

[4] R. F. Radiation Effects Progress Report, Radio Sensitivity of Cardiac Pace Makers, U.S.A.F. Aerospace Medical Division (September 1970).

The Electromagnetic Compatibility Analysis Center (EMCAC) has overall authority to control radiation sources within the DoD agencies.

In addition to the FCC and EMCAC, at least 20 other agencies are engaged in various ways with the electromagnetic compatibility problem. Within the Air Force, for example, there are the Air Force Avionics Laboratory (AFAL), the Aeronautical System Division (ASD), a Rome Air Development Center Group, the Ground Electronic Engineering Installation Agency (GEEIA), and the Electronic Systems Division (ESD). Other U.S. military sources include the Army Avionics Laboratory of the Electronics Command, the Aviation Systems Command of the Army, and the Missile and Space Command at Redstone Arsenal. Navy EMC responsibility is included in the Navy Air System Command, Navy Facilities Engineering Command, and the Navy Ship Engineering Center.

Each NASA center has a branch specializing in EMI or EMC activities. The Federal Aviation Agency (FAA) work on EMC is handled by the Radio Technical Committee for Aeronautics (RTCA).

Several societies and associations have activities directed toward compatibility or interference problems. They include the Society of Automotive Engineers, the Electronics Industries Association (EIA), and the Institute of Electrical and Electronics Engineers (IEEE). A complete list of the government agencies and their addresses can be found in the Air Force Systems Command Design Handbook 1-4, Electromagnetic Compatibility.

Radio frequency effects on biological species have become a more active investigative field since the Navy proposal to build a large ELF communications transmitter in the United States. Accordingly, the Navy, through its Bureau of Medicine and Surgery, is a leader in such research. The Air Force Aerospace Medical Division is also active.

D. Implications for DoD

The DoD risks loss of public support for its operations and procurements through radio frequency pollution. Interference with civilian electronics will not be tolerated on a continuing basis. This hazard has long been recognized and accommodated. The possible threat to biological species is new, not so obvious, and not yet so urgent. However, the radiation threat to the environment is now being raised as one objection to the construction of the Navy's proposed SANGUINE communications system. The opposition and the neutral public in this instance are not satisfied with the limited research done to date.

E. Recommendations for Further Studies

There are many different sources within the DoD that could cause interference with non-DoD equipment. There is also a large number of sensitive electronic circuits in the commercial world that could suffer interference. The number of combinations is extremely large. We should isolate the transmitter/equipment (T/E) pairs with the highest probability of having mutual problems.

Table V-1 illustrates a matrix method of identifying interference pairs. The table represents only a fraction of the number of T/E pairs that actually exist. Many of the pairs that could be generated are trivial, since to be a real offender, the transmitter must be high-power and geographically close. The frequencies need not be matched if the transmitter is high-power and near the sensitive equipment. In vehicular transmitters, the probability that the operating transmitter is close to sensitive equipment must be considered. Thus, while there is a good chance that a vehicle communications transmitter could interfere with a vehicle system, such as an electronic braking system on another vehicle, the vehicles must be near each other during the transmit period.

Table V-1

IDENTIFICATION OF INTERFERENCE PAIRS

Equipment Interferred With	Radar	Vehicle Communications	Ground Communications
Heart Pacers	0	x	x
Hospital Equipment	x	x	x
Computers	x	x	0
Vehicle Systems	0	xx	x
Navigational Aids	0	x	x
Vehicular Traffic Controls	0	xx	x

Examples of possible interference levels: 0 = minor
x = possible
xx = probable

Therefore, further study should be directed toward first estimating the probability of occurrence of possible T/E pairs, followed by analysis of equipment susceptibility. In addition, research is needed on the effects of radio frequencies on biological species. The research should span the whole frequency spectrum from direct current through ionizing frequencies. Similarly, the whole range of military power levels should be considered.

CHAPTER NINE--SPECIAL PROBLEMS

VI--NOISE

VI NOISE

Noise is of increasing environmental quality concern. Recently, it has become clear that unwanted sound could be reduced without impairing operational performance. In a large proportion of the DoD's operations, noise is generated from essentially the same sources as in the nonmilitary sector. Consequently, certain noise reductions will accrue to DoD activities simply by adopting quieter practices or products as they are introduced to the civilian sector, such as rubbish cans, office machines, and motor vehicles. However, there are DoD activities for which there are less direct civilian counterparts or for which civil and military law and administration have followed divergent paths. Also, the DoD can provide the impetus for investigation of key noise problems related to its mission that can result in benefits to the public at large. In this section several of these differences are addressed in terms of their relevance to DoD interest in noise as an avoidable pollutant.

Discussion focuses on noise associated with aircraft operations and design characteristics, as well as on the physical effects of noise and its potential health consequences. Aircraft operations are especially visible and identifiable, and noise from these sources can be directly traced; this makes them useful for the purpose of this initial examination. However, the approach outlined needs to be applied to other aspects of DoD operations that produce noise so as to ascertain the source of noise and its probable effects so that control programs may be developed and implemented.

A. Noise from Aircraft Operations

1. Statement of the Problem

The missions and aircraft of the various military installations vary greatly, resulting in diverse situations concerning aircraft noise and its impact on personnel, surrounding communities, and flown-over regions. Although general operational guidelines are designed to heighten awareness of the problem of noise to operating personnel and to minimize noise,[1] levels still may be such as to provoke adverse community responses. Reaction and alleviation measures are the responsibility of the individual base commanders.

The situations to which air base commanders must react are made complex because of local variations in a number of physical and social parameters. These include the aircraft mix; land use on the base and in surrounding communities; peculiarities of terrain; actual meteorological conditions; the socio-economic-political composition of impacted communities; public attitudes toward the installation (which are often related to economic dependence on the base); and local variations in basic philosophical values. In the case of DoD's numerous installations on foreign soil, the sociological and psychological variables can be rather different from U.S. experience. Relevant differences in foreign value systems are sometimes evident in laws concerning personal and private property damage.[2,3] Often differences in the meteorological conditions, together with differences in building construction materials, techniques, and ventilation practices, result in foreign indoor/outdoor noise ratios differing from U.S. experience.

In both domestic and foreign operations, aircraft noise abatement programs are important to the maintenance of cordial working relations.

2. State of the Art

Understanding of the influence of meteorological parameters on noise propagation is well developed. Figure VI-1 illustrates the appreciable variation in temperature and relative humidity that could be encountered at different locations or even within a few days at some locations.[4]

Sophisticated weightings of the parameters affecting reaction to aircraft noise have been developed and are illustrated by the components of a noise exposure forecast[5] as shown in Figure VI-2. Experience and accuracy in predicting response of impacted communities to various levels of noise exposure is growing,[3] including efforts by DoD.[6]

3. Present Activities

DoD sponsors numerous research projects to reduce aircraft noise at the source. These projects stem from interests in environmental noise reduction, personnel hearing conservation, and stealth of military operations. Also supported is biomedical research on hearing conservation. Relatively little effort is devoted to organizing a comprehensive approach to aircraft noise abatement that is sensitive to local variations in the complete spectrum of design, operational, and social parameters that must be considered.

4. Implications for DoD

Aircraft remain in the active inventory for a considerable time, and it seems likely that sentiment will grow against unnecessary noise. Because of this, DoD will often have to respond to increasing public pressure and awareness of the hazards of noise exposures by changing its operating procedures, as well as modifying the offending hardware.

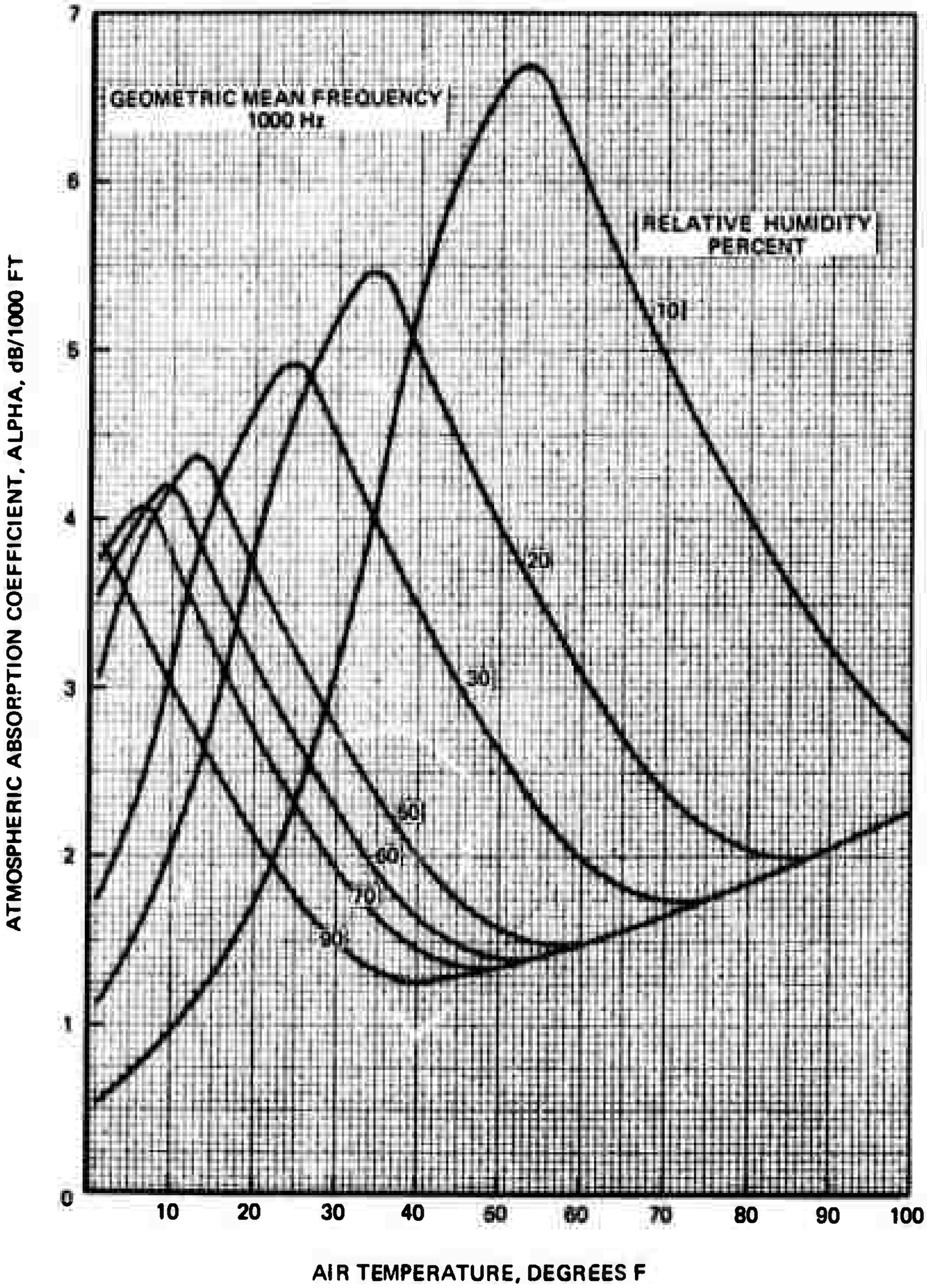

FIGURE VI-1 ATMOSPHERIC ABSORPTION COEFFICIENTS FOR ONE-THIRD OCTAVE BANDS OF NOISE FOR DIFFERENT TEMPERATURES AND HUMIDITIES

ABSOLUTE NOISE LEVELS
NOISE SPECTRUM
PNL
MAXIMUM TONE
EPNL
NOISE DURATION
AIRCRAFT TYPE
MIX OF AIRCRAFT
NEF
NUMBER OF OPERATIONS
RUNWAY UTILIZATION
FLIGHT PATH
OPERATING procedures
TIME OF DAY

SOURCE: Reference 5.

FIGURE VI-2 FACTORS INCLUDED IN COMPUTATIONS FOR PERCEIVED NOISE LEVEL (PNL), EFFECTIVE PERCEIVED NOISE LEVEL (EPNL), AND NOISE EXPOSURE FORECAST (NEF)

5. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Determine the feasibility of establishing a DoD international noise abatement clearinghouse and consulting service available to base commanders. This service would: gather, analyze, and synthesize DoD noise abatement experience; identify parameters to be measured at the local level; and evaluate current as well as anticipated changes in the base's mission and activities.
- Examine the usefulness of frequent reviews and updating of operational procedures (aided by this clearinghouse) to remain responsive to changing conditions (including meteorological and social).

B. New and Old Aircraft

1. Statement of the Problem

New aircraft soon to be entering the inventory, such as the F-14 and F-15, incorporate advances in engine design that yield lower noise levels than previous engines. These advances have been made largely in response to the need for quieter power plants for aircraft in commercial service. In the mid 1970s when these new models become operational, they will be replacing aircraft that are technologically 20 years old.[7] This indicates how long the noise levels emitted by this new generation of aircraft will have to be dealt with.

Since FAA regulations do not apply to military aircraft--besides, military aircraft often use afterburners--these aircraft enter the inventory noisier than commercial aircraft of similar vintage. Furthermore, during their expected serviceable lifetime, the next generation of commercial narrow-bodied aircraft meeting more stringent FAA standards will appear.

A contrast that will inevitably be drawn by impacted communities is between the noise levels of commercial and military aircraft. The problem lies in devising technological approaches to noise reduction that can be incorporated in new aircraft design and, through modification, in older aircraft expected to remain in service.

2. State of the Art

Turbofan engines with high bypass ratios have significantly less noise output than the turbojet engines that preceded them. However, it is believed that only about another 7 dB of noise reduction can be achieved on subsonic jets.[8] The development of modulated afterburners which allow a gradual turn-on have lessened the acoustic shock associated with afterburner ignition.

Helicopters remain noisy at low frequencies. This is especially significant, because low frequency sounds are transmitted by air farther than high frequency sounds. Hovering remains particularly objectionable because of the long exposure times.

3. Present Activities and Organizations

The tempo of aircraft noise abatement research is increasing in response to increased community pressure and FAA regulations. DoD, NASA, and manufacturers are sponsoring this research. Although the design of the F-14 and F-15 is rather far along to benefit significantly from the current research, the design of the B-1, planned to replace the B-52, is in a more favorable state of design to incorporate early research results.[9] The DoD is conducting substantial research in the reduction of noise from helicopters.

The disposition of older aircraft is an important component of noise abatement. As aircraft are retired from high priority operational status in the regular or reserve forces, they are often assigned to National Guard units for further service in training activities, or relegated to less demanding support operations. Once shifted to second class status, the noise generated by these aircraft also appears to receive second class attention. For communities exposed to noise from these aircraft, the contrast with new commercial aircraft meeting FAA noise standards will be particularly vivid.

4. Implications for DoD

Since public demands for quieter aircraft are increasing just at the time when designs for the next generation of mainstay military aircraft are becoming firm, there is a significant chance that public desires for noise abatement will not be met by the military hardware in use ten years from now. Consequently, to maintain maximum future flexibility without seriously compromising its mission, DoD should endeavor to approach FAA standards whenever possible in both design and operations that influence noise output.[10]

5. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Examine the ability of DoD to specify designs that incorporate noise as a fundamental design parameter.
- Determine the trade-offs necessary to meet noise abatement requirements, e.g., between reduced flexibility in operations and earlier retirement of obsolescent aircraft now assigned to National Guard units.
- Evaluate assignments of obsolescent aircraft with a view toward geographical reassignment or retirement when their noise levels are incompatible with progressive noise abatement programs.

C. Sonic Booms

1. Statement of the Problem

Aircraft flying at supersonic speeds create sonic booms that are generally regarded as objectionable to people and disruptive to human activity and wildlife as well. At present, no sonic booms are caused by civilian aircraft on this continent. Although it is a controversial issue, overflights by commercial supersonic aircraft may not be allowed in the United States; also hotly debated is the possibility of refusal to allow landing rights to commercial SSTs at various airports.

Since DoD has long operated supersonic aircraft over the continental United States, it has already been exposed to public criticism and has sought to alleviate the sonic boom problem by changes in operational procedures and supersonic flight paths. To some extent this approach has been successful in alleviating the problem of human exposure in urban areas. However, public concern is increasingly being drawn to sonic boom disruption in wilderness areas used as retreats from the tensions of urban living (among them noise), and ecologists have begun to receive a sympathetic ear when discussing noise as a disrupting feature for wildlife habitats. The problem is to determine the environmental impact of sonic booms to guide remedial actions.

2. State of the Art

There is no proven way to eliminate the supersonic boom. There has been progress in lowering the sound intensity of supersonic engines, mainly by clever management of the jet exhaust stream.[11] Recently the idea of an aircraft with an unsymmetric wing configuration has been suggested as a possible method of decreasing sonic booms.[12,13]

3. Implications for DoD

Since commercial service is not expected to support many SSTs, the military will continue to be the major producer of sonic booms. As further public attention is drawn to discussion of sonic booms, military activities will be under increasing scrutiny. The result may be increased pressure to curtail supersonic flights over the continent or to restrict operational discretion with respect to flight paths even further.

4. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Compile an inventory of supersonic operations for inclusion into an environmental data base that gives the home air base location, the frequency of supersonic flights, and typical flight plans by aircraft type and mission.
- Determine the extent to which relocating squadrons or redesigning operational procedures can reduce the exposure of human populations in urban and recreational areas. Similar evaluations could be made to reduce disruptions of the most noise-sensitive types of animal life.
- Assess the relative impacts of sonic booms on the environment so as to develop program guides for alleviation of adverse effects.

D. Health Consequences of Noise Exposure

1. Statement of the Problem

It is becoming increasingly evident that there is more peril to human health from noise exposure than merely the loss of hearing.[14,15] The military service and the federal government have standards for noise exposure designed to ensure hearing conservation. However, these standards are neither uniform among the services nor identical to the civilian standards.[16] As additional physiological and psychological health concerns become manifested in new civilian noise exposure regulations, the services will be under public pressure to provide equal protection for military personnel. Since the steady noises associated with military aircraft operations and the impulsive noises of military ordnance are among the most severe known, DoD may face a difficult task in this area of environmental health. The problem is to determine the scope of health consequences from noise to establish positive programs to deal with this situation effectively.

2. State of the Art

The exact nature and relevant danger thresholds for health problems (nonhearing) arising from noise are not well understood at this time, but are the subject of increasing concern and research.[3,14] The thresholds associated with hearing loss are under scrutiny and subject to more sophisticated inquiry than previously.[3,14]

3. Present Activities and Organizations

The DoD is sponsoring considerable research on noise-induced impairments sustained by both temporary and permanent personnel.[6] Concomitant research aimed at reducing aircraft noise is a large scale effort. No similar effort seems devoted to reducing impulsive noise from military ordnance. It is noteworthy that the differences in civilian and military noise exposure standards seem intended not to exclude operations using ordnance.[1]

4. Implications for DoD

The DoD should endeavor to maintain parity with changing civilian noise exposure limits for personnel. Since many of the noise environments of DoD personnel are so severe, DoD might be expected to assume a leadership role in environmental health problems associated with severe noise.

Reduction of aircraft noise is not the sole responsibility of DoD, but it is shared with many civilian agencies of government. Since ordnance is virtually the concern of DoD exclusively, a similar research program aimed at reducing the noise of weapons firing should be undertaken.

5. Recommendations for Further Studies

Among the tasks that could be logical subjects for further study are to:

- Evaluate the health related noise exposure standards of the three armed forces to determine if interservice and civilian differences are in fact warranted.
- Undertake a study to examine the ways in which ordnance activities of all scales can be made less noisy to personnel in the short run by muffling existing devices and in the long run by exploring new design and operational concepts that are inherently less noisy.

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9. Environmental Impact Statement for B-1 Aircraft, AR-43-2-AF (February 1971).

10. Federal Aviation Regulation, Part 36 - Noise Standards: Aircraft Type Certification, Federal Register, Vol. 34, No. 18355 (18 November 1969).

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12. R. T. Jones, "SST Flies on Slant Wing to Eliminate Sonic Boom," Industrial Research, Vol. 14, No. 7, p. 27 (July 1972).

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CHAPTER NINE--SPECIAL PROBLEMS

VII--ENVIRONMENTAL IMPACT OF WEAPON DEVELOPMENT AND EFFECTS TESTS

VII ENVIRONMENTAL IMPACT OF WEAPON DEVELOPMENT AND EFFECTS TESTS

A. Statement of the Problem

Throughout history there has been opposition to weapon testing. In earlier days, the opposition was based on the immediate danger to human lives and property. More recently, a whole spectrum of effects on the environment has become a public issue. In the case of nuclear testing, as evidenced by the Cannikin test, it is clear that continued underground testing, or a resumption of atmospheric testing, will increasingly have to be responsive to environmental factors.

At least five nonmanufacturing weapon-use activities have environmental impact implications.

(1) Tests--noncontainment or localization of the weapon effects is a great and generally recognized environmental hazard.

(2) Atmospheric nuclear tests, currently forbidden by treaty; contingent plans for such tests might some day be implemented.

(3) Weapon accidents during transport, handling, and operations; such incidents present a wide range of hazards including the possible release of radioactive or toxic materials.

(4) Weapon storage, which includes all the foregoing hazards. In addition, construction, occupancy, and exclusion at the storage facility alters the habits and uses of nature and man (perhaps beneficially in some cases).

(5) Simulated nuclear explosions. This is a large, growing (because of atmospheric test prohibitions), and possibly very important category for consideration. Some clearly important activities of this kind are:

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- Large chemical explosions. These tests, which often entail hundreds of tons of explosives, are a potential source of environmental harm. Common objectives of such tests are the study of blast shock and cratering, entrainment and lofting of soil and dust, and the effects of blast on items of military hardware.
- Field measurements of naturally and artificially disturbed atmospheres. These are attempts to simulate the state of the atmosphere after absorbing the energy of a nuclear explosion. Such operations are often large in scope, incorporating the use of numerous personnel, extensive ground equipment, rockets, and the injection of foreign chemicals into the upper atmosphere. They are sometimes staged outside of ecologically delicate areas. Well known examples of the kind are the SECEDE and EXCEED programs.
- Nuclear-effects-damage simulating machines. This approach to hardening military hardware uses many types of machines which may produce steady or pulsed radiation, an electromagnetic pulse, high velocity shocks, flight, etc. Although usually contained in a laboratory, full scale equipment tests are often done in the field.

These simulated nuclear weapons environments all are concentrated sources of potentially harmful energy whose support activities may also have an impact on the local environment.

B. State of the Art

To some degree, DoD weapon development programs of necessity have always sought to minimize environmental damage to receive public support. However, the approach has never been formal. A necessary first step is to make weapon development program managers sensitive to the need to minimize environmental damage. This will presumably be accomplished by the preparation and filing of impact statements. However, the full implications and consequences of filing Environmental Impact Statements are often not well established or understood. Further, those charged with preparing EISs frequently do not have adequate resources available to them for the preparation of such statements.

C. Present Activities and Organizations

All three services conduct many weapon development programs. These programs must now give more attention to environmental considerations. For example, EISs have already been prepared for the DIAMOND ORE and PACE high explosive test series which are seeking nuclear weapon effects information by simulation. These events are sponsored by the Defense Nuclear Agency in conjunction with the Office of Army Engineers and Air Force Weapons Laboratory, respectively. It is fortunate that the environmental effects of these early test cases are relatively uncontroversial and easy to predict.

In the case of nuclear testing, the Defense Nuclear Agency, which is responsible to the services for providing nuclear weapons effects information, has started surveys to determine what sources of information are available for preparing Environmental Impact Statements.

D. Implications for DoD

The implications for the DoD are delay in the development of weapons systems and delay or possible loss of a needed test program if an active environmental protection program is not undertaken. The DoD has nothing to gain by needlessly harming the environment and exposing itself to adverse publicity. In the event of a Soviet abrogation of the Limited Test Ban Treaty, public and contrived pressure against renewed nuclear testing could be expected to mount with the delay interval. Objections to the environmental effects are a likely rallying point for opposition.

E. Recommendations for Further Studies

Opposition to weapons development tests is likely to be much more muted if the public can be shown that alternatives and steps to minimize environmental impact have been carefully considered in advance. This is much more impressive than responding after objections are raised. Prudence suggests that the requirements and information needed to prepare EISs should be assembled now, especially since guidance and precedent are almost nonexistent.

Two elements in avoiding or minimizing environmental damage within weapon development and test activities are: (1) determining what harm may be done by the many facets of the activity and (2) taking steps to minimize the damage. The appropriate second step is often difficult to discern, because so often a measure taken to mitigate one effect may actually exacerbate another.

The following program, if implemented, would provide guidance for beginning the process of incorporating environmental impact and protection measures in future weapon development programs. Although this example is oriented to nuclear weapons, the plan would apply equally well to any weapon development program, particularly those concerning toxic or dangerous materials. Suggestions for further study are to:

- Write a prototype Environmental Impact Statement. The statement must consider test and operational effects on man, man's works and politics, and nature. The effects must include outright and delayed environmental damage and more subtle effects such as physical inconvenience and disruption of commerce.
- Catalog all the harmful interactions according to effect, mechanism, and result.
- Evaluate the quality of collected interaction data, noting particular areas of missing or suspicious information.

- Start a program to fill the information gaps. In the case of nuclear weapons, much information is already available on radiation effects on materials, plants, animals, and on direct explosion effects on man-made works.

- Build an input/output multiloop feedback model to study and evaluate the interdependence of the various interacting environmental effects.

- Start a program to ameliorate undesirable effects and test the efficiency of the measures in the interaction model. Using a realistic test event (a proposed operational event if possible), a technically and environmentally coordinated test plan should be designed and the trade-offs between technical goals and environmental protection compromises enunciated.

- Prepare a manual on the systematic prediction and amelioration of weapon development programs on the environment and on the preparation of Environmental Impact Statements.

APPENDICES

APPENDIX A
LISTING OF SAMPLE ENVIRONMENTAL IMPACT STATEMENTS

Appendix A

DEPARTMENT OF THE NAVY
ENVIRONMENTAL IMPACT STATEMENTS RECEIVED

Data Source Number *	Title
AR-22N	Ammunition Pier P-500, Sella Bay, Guam, Mariana Islands, June 1971 (Draft).
AR-34N	Use of Target-Ship Hulls in Exercises at Sea, August 1971 (Final).
AR-35N	Land Acquisition, Naval Security Group Activity, Homestead, Florida, August 1971.
AR-36N	Land Acquisition, Naval Submarine Base, New London, Conn., August 1971.
AR-37N	Land Acquisition, Naval Ammunition Depot, Oahu, Hawaii, January 1972.
AR-38N	Kahoolawe Island Target Complex, Hawaiian Archipelago, February 1972.
AR-39N	Land Acquisition, Sewage Disposal Facility, Naval Air Station, Lemoore, California, February 1972.
AR-40N	Relocation of Target Facilities from Aqua Cay to Cross Cay, Atlantic Fleet Weapon Range, Puerto Rico, January 1972.
AR-41N	Sanguine System, Research, Development, Test, and Evaluation, April 1972 (Final).
AR-58N	Navy F-14 Fighter Aircraft, September 1971 (Final).
AR-59N	Land Acquisition, Naval Station, Norfolk, Virginia, March 1972 (Final).
AR-60N	Dredge River Channel, Naval Submarine Base, New London, Connecticut, April 1972.
AR-80N	Exercise Exotic Dancer, Commander in Chief Atlantic, March 1972.

* Data source numbers refer to Appendix B.

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Appendix A (Continued)

DEPARTMENT OF THE AIR FORCE
ENVIRONMENTAL IMPACT STATEMENTS RECEIVED

Data Source Number	Title
AR-42AF	Disposition of Orange Herbicide by Incineration, January 1972.
AR-43AF	B-1 Aircraft, February 1972.
AR-44AF	Land Outlease for Wastewater Treatment Facilities, Tyndall AFB, Florida, March 1972.
AR-45AF	Runway Extension, Keesler AFB, Mississippi, March 1972 (Draft).
AR-46AF	Over-the-Horizon (OTH) Radar System, Continental United States, March 1972.
AR-47AF	National Guard Use of Arnold Engineering Development Center, April 1972 (Final).
AR-48AF	Pacific Cratering Experiments (PACE), April 1972 (Draft).
AR-49AF	500 Units of Military Family Housing, Shaw Air Force Base, South Carolina, May 1972.
AR-50AF	Outlease of Land to Gulf Power Company, Eglin Air Force Base, Florida, March 1972 (Draft).
AR-53AF	F-15 Aircraft, September 1971 (Final).
AR-54AF	1550th Air Training and Test Wing (MAC), Hill Air Force Base, Utah, November 1971 (Final).
AR-71AF	Advanced Ballistic Reentry Systems (ABRES), Radioactive Sensors, January 1972 (Draft).
AR-79AF	The Air Force Academy Airmanship Program (Draft).

Appendix A (Continued)

DEPARTMENT OF THE ARMY
ENVIRONMENTAL IMPACT STATEMENTS RECEIVED

Data Source Number	Title
AR-63A	Disposal of Anti-Crop Biological Agent, Beale Air Force Base, California and Rocky Mountain Arsenal, Colorado, July 1971, (Final).
AR-64A	New Walter Reed General Hospital, Washington, D.C., September 1971 (Final).
AR-65A	Safeguard Ballistic Missile Defense System, No. Dakota and Montana Deployment Areas, October 1971 (Final).
AR-66A	Minimum Facilities for Air Cavalry Combat Brigade Test, Fort Hood, Texas, November 1971 (Final).
AR-67A	Destruction of Anti-Crop Biological Agent, Ft. Detrick, Maryland, December 1971, (Final).
AR-68A	Airfield Complex, Campbell Army Airfield, Fort Campbell, Kentucky, February 1972. (Final)
AR-69A	Wesyern Medical Institute of Research, Presidio of San Francisco, California, March 1972 (Final).
AR-70A	Relocation of Harry Diamond Laboratories, White Oak, Maryland, April 1972 (Final).
AR-61A	Disposal of Anti-Personnel Biological Agents and Weapons, Pine Bluff Arsenal, Arkansas, April 1971 (Final).
AR-62A	Project Eagle--Phase I. Disposal of Chemical Agent Mustard at Rocky Mountain Arsenal, Colorado, July 1971 (Final).
AR-81A	Diamond Ore, Phase II, High Explosive Cratering Experiments, January 1972 (Draft).
AR-82A	Transportable Disposal System, June 1971.
AR-83A	Demilitarization of Toxic Munitions at U.S. Army Materiel Command Installations, October 1971 (Draft).
AR-84A	Safeguard Ballistic Missile Defense System, Missouri, Wyoming, or Washington, D.C., November 1971 (Draft).
AR-86A	Task Force Eagle--Plan for the Demilitarization and Disposal of the M34 GB Cluster at Rocky Mountain Arsenal, October 1971.

Appendix A (Continued)

DEFENSE SUPPLY AGENCY
ENVIRONMENTAL IMPACT STATEMENTS RECEIVED

Data Source Number	Title
AR-85DSA	Policies Relating to Procurement of Coal for Military Installations and Civil Agencies, February 1972 (Draft).

Appendix A (Concluded)

ENVIRONMENTAL IMPACT STATEMENTS NOT RECEIVED*

Department of the Navy

Underwater Demolition of Ordnance, Island of Culebra, Puerto Rico, December 1971.

Dock Basin, Naval Station, Newport, Rhode Island.

Sanitary Land Fill, Portsmouth Naval Station, Portsmouth, New Hampshire.

Department of the Air Force

Office Building, Bolling AFB, Maryland.

Land Acquisition, Maine.

Air Installation Compatible Use Zone Program (AICUZ).

Change in Mission, Luke AFB, August 1970.

Sonic Booms, March 1972.

High Energy Laser Program, November 1971.

Department of the Army

Operation CHASE - Ocean Disposal of Concrete Vaults Containing Chemical Munitions, Florida, July 1970 (Final).

Operation Red Hat - Transportation of Chemical Munitions from Okinawa to Johnston Island, November 1970 (Final).

Military Ocean Terminal, Sunny Point, North Carolina, May 1972.

Biological Demilitarization, Colorado, Maryland, Arkansas, November 1971.

Family Housing, Oahu, Hawaii.

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* The validity of this listing is uncertain. It is not clear whether impact assessments or statements have, in fact, been prepared for all of the noted actions.

APPENDIX B
SUMMARY OF DATA SOURCES

Appendix B

DATA SOURCE DESCRIPTION*

Number	Description
AR-1	Support of Environmental Program Planning for the Advanced Research Projects Agency, SRI EGU 71-187, 5 January 1972, R. M. Rodden. Proposal to Dr. Stanley Ruby.
AR-2	Federal Register, Vol. 37, No. 35, p. 3772, 19 February 1972. Responsibilities, Functions, and Authorities of the Assistant Secretary of Defense for Health and Environment. Defines above, including establishment of requirements for DoD research and development programs to be carried out by DDR and E.
AR-3	Department of Defense Directive Number 6050.1, 9 August 1971, Environmental Considerations in DoD Actions. Establishes DoD policy, assigns responsibilities, and provides guidance for implementation of NEPA, etc.
AR-4	U.S. Organization Charts. Selected charts indicating DoD, DDR and E, ARPA, and others.
AR-5	Statement of Dr. Richard S. Wilbur, Assistant Secretary of Defense (Health and Environment) to the Senate Armed Services Subcommittee for Research and Development. Draft of statement that covers history of DoD Pollution Committee and current and planned activities of Dr. Wilbur's office. A useful review document on DoD activities concerning environmental quality.

* Environmental Impact Statements are marked by an asterisk before the number and a letter suffix of N, AF, A, DSA, for the Navy, Air Force, Army and Defense Supply Agency, respectively.

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Appendix B (Continued)

Number	Description
AR-6	Status of U.S. Army's R&D in Environmental Quality, J. W. Moberly, Stanford Research Institute, 24 March 1972. Describes Mr. Moberly's collected information to date on Army programs. Good summary of personnel, facilities, and so forth.
AR-7	Cleanup Orders Hit Federal Facilities, Env. Sci. and Tech., 5, No. 12, 1176-77 (December 1971). Review article. Includes comments by Col. Herbert Bell of Office of Deputy Assistant Secretary of Defense for Environmental Quality.
AR-8	Army Engineers and EPA at Odds Over Sewage Treatment Programs, National Journal (25 December 1971). Discusses conflicts on responsibilities--possible need for congressional action.
AR-9	The Man from DDR&E, Aerospace Facts (October-December 1971). Discussion of responsibilities of G. R. Makepeace for coordination of exploratory development, advanced development, and supporting research in engineering technology for DoD.
AR-10	Deep Sea Disposal of Liquid and Solid Wastes, David D. Smith and Robert P. Brown, Dillingham Engineering Co., Industrial Water Engineering, pp. 20-23 (September 1970). Review of study funded by Bureau of Solid Waste Management, USPHS (now in EPA). General discussion of findings.
AR-11	"Pollution's Last Gasp," Soldiers, 26, No. 1 (November 1971). Review article describing highlights of Army activities for controlling air quality.
AR-12	Environmental Pollution Monitoring Data Bases--A list of some 16 agencies or groups having data bases relevant to environmental quality. Compiled by EPA.

Number	Description
AR-13	Environmental Research Laboratories in the Federal Government--An Inventory, Volumes I and II, Policy Institute of Syracuse University Research Foundation, September 1971. Prepared for National Science Foundation, Office of Research Applications. Comprehensive survey of existing in-house capabilities in environmental research in the federal government. Covers some 50-60 separate entities. Gives good description of methodology, scope (and limitations thereof), and criteria. In two separately bound volumes.
AR-14	Contract Description of Work, NR 089-091, Code 418, 29 March 1972. Work Statement for Project from R. Gracen Joiner accompanied by memos from Dr. Ruby, G. Dorough of DDR&E, and Mr. John Busterud, Deputy Assistant Secretary of Defense for Environmental Quality.
AR-15	"Government Backs Environment," Env. Sci. and Tech., 6, No. 3, pp. 207-211 (March 1972). Review article on federal environmental programs. Discusses budget, programs, and Environmental Impact Statements.
AR-16	Third Annual Symposium on Environmental Pollution, 17-18 May 1972, Industrial College of the Armed Forces, Fort McNair, Washington, D.C. Copy of Program sponsored by DoD, EPA, U.S. Maritime Administration, and U.S. Coast Guard.
AR-17	"Study of the Environmental Impact Statement as a Tool for Environmental Quality Management," a Concept Paper by L. W. Weisbecker and W. W. Hill, Stanford Research Institute. Draft paper includes a good summary of legal and policy background pertaining to NEPA, CEQ, and current status of Environmental Impact Statements.

Number	Description
AR-18	Public Law 91-190, 91st Congress, S. 1075, 1 January 1970, An Act To Establish a National Policy for the Environment To Provide for the Establishment of a Council on Environmental Quality and for Other Purposes. Copy of the Act known as NEPA formulating the need for and outline of Environmental Impact Statements. Also establishes and describes the Council on Environmental Quality.
AR-19	"A Procedure for Evaluating Environmental Impact," L. B. Leopold et al., U.S. Geological Survey Circular 645, Washington, D.C. (1971). Primary purpose of methodology is to ensure that the impact of alternative actions is evaluated and considered--that is, nothing is left out. Also serves as a guide in preparing statement required by Section 102(2)(C) of NEPA. Includes a large matrix of existing characteristics and conditions of the environment versus proposed actions that may cause environmental impact.

Number	Description
AR-20	Proposed Guidelines for the Preparation and Evaluation of Environmental Impact Statements under the California Environmental Quality Act of 1970, State of California, Office of the Secretary for Resources, 1416 Ninth Street, Suite 1311, Sacramento, California 95814, 21 June 1971. Guidelines, criteria, and procedures for preparation and review of environmental impact statements. Includes review procedures for federal projects. EIP requirements appear similar to NEPA.
AR-21	Environmental Quality, the Second Annual Report of the Council on Environmental Quality, Stock No. 4111-0005, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, August 1971. Reviews, actions, and events of past year, environment and economy, environment and law, and status and trends, Appendix G presents agency guidelines for preparation, distribution, and review of impact statements.
*AR-22N	Environmental Impact Statement, Ammunition Pier P-500, Sella Bay, Guam, Mariana Islands, Department of the Navy, Office of the Secretary, Washington, D.C. 20350, June 1971. Submitted to CEQ in August 1971. Draft statement covers proposed new pier at safer location. Considered as alternatives 21 other sites, construction of an open pier, and a wharf in lieu of a pier.
AR-23	A Dynamic Empirical-Input Model to Assist the Measurement and Control of Environmental Impact, George G. Barnes, Technical Note, IRD Project No. 830531-02-AOB, Stanford Research Institute, 30 December 1971. Derives a model of user-resource interactions to assist measurement and control of environmental impact.

Number	Description
AR-24	Environmental Impact Seminar, Memorandum from F. L. Ludwig to John Eikelman, dated 28 April 1972. Summarizes highlights of the Federal Executive Board Environmental Impact Statement Seminar held on 25 April 1972 in Chicago. Speakers included William Dircks of CEQ, Sheldon Meyers of EPA, Charles Nelson of OMB, Larry Cohen, Office of U.S. Attorney. Federal agencies preparing and reviewing EIS included Gordon Hanson of Corps of Engineers, Lester Case of FAA, Edwin P. Holahan of Federal Highway Administration (FFWA), Rico Conti of AEC, and Ed Levin of HUD.
AR-25	Environmental Impact Analysis, Leo W. Weisbecker, Stanford Research Institute IR&D Document, January 1972. Discusses evolution and operation of NEPA and resulting impact analyses. Proposes study to evaluate effectiveness of 102 statement program as a tool for management of environmental quality.
AR-26	102 Monitor, Environmental Impact Statements, Council on Environmental Quality. Available issues as of May 1972 include November 1971 (Vol. 1, No. 10), December 1971, January 1972, and February 1972. Presents general information on 102s, recent statements received, and cumulative summary of 102s filed since 1 January 1970.
AR-27	Administration of the National Environmental Policy Act, Parts 1 and 2, Hearings before the Subcommittee on Fisheries and Wildlife Conservation of the Committee on Merchant Marine and Fisheries, Ninety-First Congress, Second Session, December 1970, Serial No. 91-41. Purpose of the hearings, as described by Hon. John D. Dingell, chairman, was to determine the effectiveness of the NEPA, and the adequacy of agency responses to sections 102 and 103 of the act, and to determine what changes, if any, may be called for to improve and to articulate the objectives of the act. Voluminous testimony by representatives of all major federal agencies. DoD testimony, like others, generally gives

Number	Description
AR-27 (cont.)	impression of services attempting to define responsibilities and actions with respect to NEPA. Useful as a reference source but more recent and pertinent information is provided by AR-2, AR-3, and AR-5.
AR-28	Department of Defense Environmental Quality Program Status, January 1972, Office of the Deputy Assistant Secretary of Defense for Environmental Quality. Useful summary of DoD activities in environmental quality. Defines current organizational responsibilities and overviews of activities of the Defense Supply Agency and of the Departments of the Army, Navy and Air Force. Also presents 1972 and proposed 1973 military construction programs.
AR-29	Protection and Enhancement of Environmental Quality, AF Regulation 19-1, Department of the Air Force, Headquarters U.S. Air Force, Washington, D.C. 20330, 18 February 1972. Establishes policies, assigns responsibilities, and provides criteria and standards for an environmental pollution abatement program. Implements DoD Directive 5100.50, 23 June 1970 and in part DoD Instruction 4120.14, 14 May 1971, DoD Directive 5030.41, 23 May 1969, DoD Directive 6050.1, 9 August 1971, and the Rivers and Harbors Act of 1899.
AR-30	Environmental Assessments and Statements, AF Regulation 19-2, Department of the Air Force, Headquarters, U.S. Air Force, Washington, D.C. 20330, 20 January 1972. Establishes policies, assigns responsibilities, and provides guidance for the preparation of environmental assessments and statements. Implements DoD Directive 6050.1, 9 August 1971.
AR-31	Special Report, The Army, Its Military Activities, and the Environment During 1970, George A. Cunney, Jr., PE, Environmental Office, Office Director of Installation, Office of the Deputy Chief of Staff for Logistics, Department of the Army.

Number	Description
AR-31 (cont.)	A useful summary of Army problems and programs. Discusses organizational changes, air pollution, water pollution, research and development, and budget data for construction program through FY 1972.
AR-32	Current Fiscal Year 1972-1973 Programs for the Control of Pollution from Army Installations and Equipment, Office of the Deputy Chief of Staff for Logistics, Department of the Army, Washington, D.C. 20310. Extends budget data through FY 1973, and expands the scope of the earlier information presented in AR-31 above.
AR-33	Schedule for Study of Improved Air Pollution Abatement Systems for Jet Engine Test Cells, N62399-72-R-0020, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, 17 May 1972. Invitation to submit qualifications and interest in proposed study. Document discusses some background on nature of test cell problems.
*AR-34N	Use of Target-Ship Hulls in Exercises at Sea, Final Environmental Impact Statement, Department of the Navy, August 1971. Describes sinking of approximately 15 ship hulls per year for purposes of training and weapon evaluation.
*AR-35N	Land Acquisition, Naval Security Group Activity, Homestead, Florida, Department of the Navy, August 1971. Describes acquisition of 568 acres of unimproved swampland to prevent commercial encroachment.
*AR-36N	Land Acquisition, Naval Submarine Base, New London, Connecticut, Department of the Navy, August 1971. Describes acquisition of 36 acres of unimproved land to increase explosive safety zone for naval magazines.

Number	Description
*AR-37N	Land Acquisition, Naval Ammunition Depot, Oahu, Hawaii, Department of the Navy, January 1972. Acquisition of land to increase explosive buffer zone from ammunition loading pier.
*AR-38N	Kahoolawe Island Target Complex, Hawaiian Archipelago, February 1972. Covers proposal to continue use of approximately 7800 acres of Kahoolawe Island as a bombing target.
*AR-39N	Sewage Disposal Facility (Land Acquisition), Naval Air Station, Lemoore, California, 19 February 1972. Proposal to acquire approximately 440 acres of land to build a sewage treatment facility based on oxidation and evaporation ponds.
*AR-40N	Relocation of Target Facilities from Aqua Cay to Cross Cay, Atlantic Fleet Weapon Range, Puerto Rico, Department of the Navy, January 1972. Movement of target facility to a larger island located a greater distance from inhabited island of Culebra.
*AR-41N	Sanguine System, Final Environmental Impact Statement for Research, Development, Test and Evaluation, Department of the Navy, April 1972. In two large volumes. The first volume contains seven parts corresponding to the EIS guidelines, plus two appendixes covering comments and public interest. The second volume contains Technical Annexes that provide the technical data used for the EIS.
*AR-42AF	Disposition of Orange Herbicide by Incineration, Department of the Air Force, January 1972. Concerned with problem of disposing of a large quantity of Orange herbicide. Solution proposed requires transportation of existing surplus to selected site for incineration.

Number	Description
*AR-43AF	B-1 Aircraft Environmental Impact Statement, Department of the Air Force, February 1972. Manned bomber intended to replace B-52 as complement to ICBM and SLBM weapon systems. Will operate at high altitude with supersonic capability in excess of Mach 2.
*AR-44AF	Land Outlease for Wastewater Treatment Facilities, Tyndall AFB, Florida, AF-ES-72-80, Department of the Air Force, March 1972. Proposal to lease 150 acres of Air Force land to nearby communities and industry for joint waste water treatment facility.
*AR-45AF	Runway Extension, Keesler AFB, Mississippi, AF-ES-72-4D, Department of the Air Force, March 1972. Proposes to extend runway from present 5000 feet to 6000 feet.
*AR-46AF	Over-the-Horizon (OTH) Radar System, Continental United States, AF-ES-72-50, Department of the Air Force, March 1972. Covers proposed construction of two radar sites, one in Maine and one in state of Washington. Final site selections not yet made.
*AR-47AF	National Guard Use of Arnold Engineering Development Center, AF-ES-72-10F, Department of the Air Force, April 1972. Proposes to make available to Tennessee National Guard for training of mechanized units, 2500 acres of land near Tullahoma, Tennessee.
*AR-48AF	Pacific Cratering Experiments (PACE), AF-ES-72-10D, Department of the Air Force, April 1972. Detonation of a series of high-explosive charges at the air-ground interface of selected islands at Eniwetok Atoll, Marshall Islands. Purpose is to assess both U.S. and potential enemy hardened strategic systems by extrapolation of HE data to earlier nuclear events.

Appendix B (Continued)

Number	Description
*AR-49AF	500 Units of Military Family Housing, Shaw Air Force Base, South Carolina, AF-ES-72-12D, Department of the Air Force, May 1972. Proposes acquisition of 100 acres of land on which to build 500 family housing units. Site is contiguous to existing base housing comprising 1205 units.
*AR-50AF	Outlease of land to Gulf Power Company, Eglin Air Force Base, Florida, AF-ES-72-11D, Department of the Air Force, March 1972. Installation of new 230,000 volt power transmission lines to back up existing power net serving Eglin Air Force Base and the Fort Walton Beach area.
AR-51	Environmental Considerations in DA Actions, RCS DD-H&E (AR) 1068, DAAG-PAP (1 September 1971) DALO-IN, Department of the Army, Office of the Adjutant General, Washington, D.C. 20310, 21 October 1971. Army guidelines for environmental consideration. Guidelines prescribe policies and responsibilities and establish procedures for the implementation of Section 102(2) of NEPA.
AR-52	Watchdog Audits Environmental Programs, <u>Env. Sci. and Tech.</u>, 6, No. 5 (May 1972). Review article discussing General Accounting Office role in evaluating whether federal agencies are meeting requirements of legislative action.
*AR-53AF	Final Environmental Statement for F-15 Aircraft, 17 September 1971, Department of the Air Force, Headquarters, USAF, PB-201 710F. Condensed statement explaining need for F-15, associated significant problems of noise and air pollutants, and current and planned research programs on noise and air pollutant suppression.

Number	Description
*AR-54AF	1550th Air Training and Test Wing (MAC), Hill Air Force Base, Utah, Final Environmental Statement, AF-ES-71-1F, Department of the Air Force, Washington, D.C., 2 November 1971, PB-198 764-F. Consolidation of all Air Force advanced helicopter training at Hill AFB, Utah. Main impacts on noise and air quality.
AR-55	Analysis of Aircraft Exhaust Emission Measurements: Statistics, H. T. McAdams, Cornell Aeronautical Laboratory, Inc., CAL Report No. NA-5007-K-2, 19 November 1971, PB 204869. Phase II Report which applies statistical procedures to the analysis of mass emission data acquired during Phase I studies. Mainly directed toward analytical methods rather than air quality problems.
AR-56	Atmospheric Pollution by Aircraft Engines and Fuels, A Survey, R. F. Sawyer, Advisory Group for Aerospace Research and Development, North Atlantic Treaty Organization, AGARD Advisory Report No. 40, March 1972. Identified over 100 relevant programs as a result of contracts with 45 organizations in the United States, United Kingdom, France, The Netherlands, Belgium, Germany, and Italy. Gives summary data on problem and supports 27 current or potential problem areas requiring investigation. Good bibliography included.
AR-57	Recommendations for Improving Agency NEPA Procedures, Memorandum for Agency and General Counsel Liaison on NEPA Matters, Environment Reporter, 19 May 1972. CEQ recommendations that take account of judicial decisions construing NEPA. Total of 10 recommendations covering all aspects of EIS preparation.
*AR-58N	Navy F-14 Fighter Aircraft, Final Environmental Impact Statement, Department of the Navy, September 1971, PB-199 851-F. Describes environmental impact of proposed aircraft which is now in advanced development stage. Primary impacts are concerned with air quality and noise.

Number	Description
*AR-59N	Land Acquisition, Naval Station, Norfolk, Virginia, Department of the Navy, March 1972, PB-201 855-F. Describes acquisition of 508 acres of railroad yard facilities for eventual construction of Navy administrative, storage/supply, and waterfront facilities.
*AR-60N	Dredge River Channel, Naval Submarine Base, New London, Connecticut, Department of the Navy, April 1972, PB-208 175-D. Deepening and widening of existing navigation channel from New London, Connecticut, to Long Island Sound. Distance of approximately 75 miles and deepening from 33 to 37 feet.
*AR-61A	Disposal of Anti-Personnel Biological Agents and Weapons, Pine Bluff Arsenal, Arkansas, Department of the Army, 14 April 1971, PB-198 900-F. Plans for demilitarization of all stocks of antipersonnel agents and weapons, including toxins, at Pine Bluff Arsenal, Arkansas.
*AR-62A	Project Eagle--Phase I, Disposal of Chemical Agent Mustard at Rocky Mountain Arsenal, Denver, Colorado, July 1971, Department of the Army, PB-200 540-F. Plan for disposal of bulk mustard stocks by incineration. Total of 3,407 one-ton containers containing 3,071 tons of mustard.
*AR-63A	Disposal of Anticrop Biological Agent, Beale Air Force Base, California and Rocky Mountain Arsenal, Colorado, July 1971, Department of the Army, PB-201 259-F. Destruction by inactivation in sites with carboxide gas, followed by incineration. Similar operations at each installation.
*AR-64A	New Walter Reed General Hospital, Washington, D.C., September 1971, Department of the Army, PB-199 314-F. Construction of a new general hospital in northcentral section of the District of Columbia. New facility will contain 1280 beds and replace old hospital.

Number	Description
*AR-65A	Safeguard Ballistic Missile Defense System, North Dakota and Montana Deployment Areas, October 1971, Department of the Army, PB-203 321-F. Two deployments near Minuteman fields near Grand Forks, North Dakota, and Malmstrom AFB, Montana. Each deployment to consist of two radar sites and four remote launch sites.
*AR-66A	Minimum Facilities for Air Cavalry Combat Brigade Test, Fort Hood, Texas, November 1971, Department of the Army, PB-202 796-F. Relates to construction of facilities at Fort Hood, Texas, to provide minimum essential heliport and testing facilities for up to 410 helicopters. Impacts discussed concerned with air quality, water quality, land use, noise, and wild life.
*AR-67A	Deactivation of Anti-Crop Biological Agent, Ft. Detrick, Maryland, December 1971, Department of the Army, PB-205 226-F. Action similar to AR-63A above but at Fort Detrick, Maryland. Deactivation with carboxide gas followed by incineration.
*AR-68A	Airfield Complex, Campbell Army Airfield, Fort Campbell, Kentucky, February 1972, Department of the Army, PB-206 761-F. Construction, in three phases (FY 1972, FY 1973, and FY 1974), of facilities primarily to support helicopter operations including assault battalions, aerial field artillery, aerial cavalry, and aviation elements of divisional artillery.
*AR-69A	Western Medical Institute of Research, Presidio of San Francisco, California, Department of the Army, March 1972, PB-199 312-F. Covers construction of facilities for medical research and development in a single laboratory.

Number	Description
*AR-70A	Relocation of Harry Diamond Laboratories, White Oak, Maryland, April 1972, Department of the Army, EIS-MD-72-4449-F. Relocation of laboratories from present site in Washington, D.C. to White Oak, Maryland.
*AR-71AF	Advanced Ballistic Reentry Systems (ABRES), Radioactive Sensors, AF-ES-72-60, January 1972, Department of the Air Force, PB-207 577-D. Draft statement for the use of radioactive materials (primarily Ta-182 and Co-57) as sensors for evaluation of nose cone ablation during reentry.
AR-72	Congressional Record - House, H4209, 20 May 1971. Statement by Mr. Hechler of West Virginia concerning the purchase of coal by the Defense Fuel Supply Center and the suggested need for preparation of an Environmental Impact Statement.
AR-73	The Operation of the National Environmental Policy Act of 1969, Joint Hearings before the Committee on Public Works and the Committee on Interior and Insular Affairs, United States Senate, Ninety-Second Congress, Second Session, 1, 7, 8, and 9 March 1972, Serial No. 92-H32. Hearings include a response from Dr. Richard S. Wilbur, Assistant Secretary of Defense (Health and Environment) to Hon. Russell E. Train outlining delays caused by NEPA. Such delays were all centered on the civil works program of the Corps of Engineers.
AR-74	National Environment Policy Act: Signs of Backlash are Evident, Science, Vol. 176, pp. 30-33 (7 April 1972). Discussion of agency dissatisfaction with actions stemming from NEPA that have delayed implementation of projects.
AR-75	National Environmental Policy Act: How Well Is It Working?, Science, Vol. 176, pp. 146-150 (14 April 1972). Review of operation of NEPA and apparent uncertainty concerning overall beneficial effects.

Number	Description
AR-76	Conservation Foundation Letter, May 1972, The Conservation Foundation, Washington, D.C. 20036. Reviews progress of NEPA over two and one-half years of operation and conservationists concerns over attacks against the law.
AR-77	Summary of Oil and Sewage Abatement Programs in the U.S. Navy, Task Group on Research and Development of Marine Environmental Affairs, Office of Chief of Naval Operations, Department of the Navy, 9 June 1972. Summary of programs prepared for Deputy Undersecretary of the Navy. Descriptions of problems, actions, and research and development.
AR-78	Environmental Impacts of Polystyrene Foam and Molded Pulp Meat Trays - A Summary, W. E. Franklin and R. G. Hunt, Midwest Research Institute Report No. MRI 3554-D, 24 April 1972. Summary describes use of environmental analysis that begins with virgin raw materials and energy inputs and extends through all processes to final product use and disposal.
*AR-79AF	The Air Force Academy Airmanship Program, Department of the Air Force, Draft Environmental Statement, PB-207 908-D. Proposed project to provide facilities at Air Force Academy for relocating T-41 trainers from Peterson Field in Colorado Springs.
*AR-80N	Exercise Exotic Dancer, Commander in Chief Atlantic, March 1972, PB 207 741 D. Joint Chiefs of Staff directed exercise to evaluate capability of assigned Army, Navy, Air Force, and Marine Corps units to operate in a joint service environment as part of the Atlantic Command. All facets of joint military operations on land, on and under the sea, and in the air included. Operations area mainly military bases in North Carolina.

Number	Description
*AR-81A	Diamond Ore, Phase II, High Explosive Cratering Experiments, Department of the Army, Draft Environmental Statement, January 1972. Cratering experiments that are a part of an Army research project to simulate the effects that different types of stemming will have on the cratering properties of subsurface emplaced nuclear explosives.
*AR-82A	Transportable Disposal System, Environmental Statement, Department of the Army, June 1971, PB 202 308 D. Describes a modular system that can be transported to various storage sites and used to dispose of chemical munitions, including munitions, nerve gas, and mustard.
*AR-83A	Demilitarization of Toxic Munitions at U.S. Army Materiel Command Installations, Department of the Army, Draft Environmental Statement, October 1971, PB 203 509 D. On site disposal of small numbers of leaking or defective chemical munitions plus other munitions. Method chosen was chemical detoxification. Sites in Alabama, Kentucky, Colorado, Utah, and Oregon.
*AR-84A	Safeguard, Ballistic Missile Defense System, Department of the Army, Draft Environmental Statement, November 1971, PB 204 162 D. Deployment of third site within Minuteman field in Missouri and a fourth site in Wyoming or near National Command Authority, Washington, D.C.
*AR-85DSA	Policies Relating to Procurement of Coal for Military Installations and Civil Agencies, Defense Supply Agency, Draft Environmental Statement, February 1972, PB 207 469 D. Action relates to procurement of coal by DSA. Coal produced by mining operations in 16 states that have associated environmental impacts. Agency proposes to revise contractual procedures to help reinforce current reclamation requirements and existing laws.

Appendix B (Continued)

Number	Description
*AR-86A	Task Force Eagle - Plan for the Demilitarization and Disposal of the M34 GB Cluster at Rocky Mountain Arsenal, Environmental Impact Statement, Department of the Army, October 1971, PB 204 919 D. Phase II of an action for the disposal of obsolete cluster bombs containing the chemical warfare nerve agent GB. GB agent detoxified by chemical neutralization. Replaces earlier plans under Operation Chase.
AR-87	U.S. Navy Research and Development for Environmental Protection, Pamphlet, Chief Naval Material, U.S. Navy (1972). Brief summary of Navy R&D programs directed to environmental quality problems.
AR-88	Summary Report of the Conference on Status of Army R&D in Environmental Quality, Department of the Army, Office of the Chief of Research and Development, 8-9 December 1971. Document provided by Maj. Jerry L. Gregg, Life Sciences Div. Army Research Office. Gives good summary of Army R&D programs in environmental quality research.
AR-89	Methodology for Environmental Impact Statement Preparation, U.S. Army Construction Engineering Research Laboratory, Urbana, Illinois. Brief task summary provided by Maj. Jerry L. Gregg, Army Research Office, on 7 September 1972. Work at CERL led by Mr. Tim Lewis and Dr. Mackenzie Davis.
AR-90	Environmental Quality, the Third Annual Report of the Council on Environmental Quality, Stock No. 4111-0011, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, August 1972. Major sections on environmental indices, forecasting, international aspects, NEPA, economic factors. Several useful appendices.

Number	Description
AR-91	Environmental Protection Research Catalog, Stock No. 5501-0364, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1972). In two parts, the catalog includes 5488 project descriptions covering air quality, water quality, solid wastes, pesticides, radiation, and noise. Part 1 presents abstracts and Part 2 contains indices by subject, investigator, and performing and supporting organizations.
AR-92	Concept Definition of the Navy Environmental Protection Data Base (NEPDB) System, compiled by D. N. Berg, Stanford Research Institute, Project No. 1889 (15 August 1972). Analyzes user requirements for environmental data and develops characterizations of data base components. Also develops a plan for system implementation together with total costs.

Appendix C

PRELIMINARY COMPILATION OF PRESENT DOD RESEARCH TASKS RELATED TO ENVIRONMENTAL QUALITY

Research Area	Number of Research Tasks		
Air Quality			92
A. Emission Sources		9	
1. Aircraft Engines	3		
2. Surface Combustion Engines	3		
3. Incineration	2		
4. Stratospheric Rockets	1		
B. Effects on Humans		10	
1. Materials Testing	2		
2. Psychological Effects	2		
3. Closed Systems	2		
4. Toxic Gases	2		
5. Dental Aerosols	1		
6. Human Generated Contaminants	1		
C. Effects on Animals, Plants		6	
1. Toxic Gases	3		
2. Explosives Testing	1		
3. Materials Testing	1		
4. Optimum Growth	1		
D. Economic Aspects	-		
E. Legal, Administrative, Social	-		
F. Control Methods		17	
1. Air Pollution Abatement	4		
2. Aircraft Exhausts	4		
3. Combustion Engines	3		
4. Fire Fighting	1		
5. Rocket Exhaust	1		
6. Incineration	1		
7. Detectors	1		
8. Closed Atmospheres	1		
9. Materials Testing	1		

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Appendix C (Continued)

Research Area	Number of Research Tasks		
G. Measurements		28	
1. Detectors	11		
2. Air Pollution Abatement	6		
3. Closed Atmospheres	2		
4. Aircraft Exhausts	2		
5. Combustion Engines	2		
6. Air-Water Interface	1		
7. Turbulence	1		
8. Rocket Exhausts	1		
9. CO_2 in Cold Regions	1		
10. Remote Sensing	1		
H. Basic Research	3	22	
1. Pollution Control	4		
2. Diffusion	1		
3. Emissions	3		
4. Effects on Humans	3		
5. Pollution Detection	2		
6. Environmental Studies	2		
7. Visibility	1		
8. Atmospheric Electricity	1		
9. Materials Testing	1		
10. Weather Modification	1		
Water Quality			155
A. Emission Sources		25	
1. Dredging	8		
2. Oil Pollution	5		
3. Dam Construction	3		
4. Explosives Testing	2		
5. Solid Waste	2		
6. Deep Water Disposal	1		
7. Ocean Trace Elements	1		
8. Lagoons	1		
9. Radioactive Waste	1		
10. Eutrophication	1		

Appendix C (Continued)

Research Area	Number of Research Tasks	
B. Pollution Identification		22
1. Beaches and Near-shore	6	
2. Water Analysis	5	
3. Ocean Oil	5	
4. Ocean Dumping	2	
5. Pollution Control	1	
6. Phosphate	1	
7. Storm Runoff	1	
8. Remote Sensing	1	
C. Water Treatment		6
1. Field Purification	3	
2. Germicidal Formulations	2	
3. Ion Exchange	1	
D. Water Management and Pollutant Disposal		43
1. Oil Spills	14	
2. Estuaries	4	
3. Ecological Capability	4	
4. Turbulent Diffusion	3	
5. Waste Disposal	3	
6. Materials Testing	3	
7. Facility Construction	2	
8. Water Treatment	2	
9. Enforcement and Control	2	
10. Insecticide Detoxified	1	
11. Mine Waters	1	
12. Ground Water Dating	1	
13. Radiation	1	
14. Air-Sea Interaction	1	
15. Radioactive Fallout	1	
E. Waste Treatment		47
1. Facility Development	19	
2. Microbiological Treatment	7	
3. Shipboard Treatment	5	
4. Stabilization Pond	4	
5. Waste Reclamation	4	
6. Evaluation Procedure	3	
7. Aeration	2	
8. Pollutant Removal	2	
9. Radiation Treatment	1	

Appendix C (Continued)

Research Area			Number of Research Tasks
F. Pollution Effects		12	
1. Environmental Studies	5		
2. Biological Fouling	2		
3. Thermal Pollution	2		
4. Oil Spills	2		
5. Deep Water Disposal	1		
Solid Waste Management			3
A. Agricultural Sources		1	
1. Bird Strikes	1		
B. Industrial Sources		0	
C. Municipal Sources		0	
D. Collection, Transportation, Disposal		2	
1. Chemical Agent	1		
2. Radioactive Waste	1		
Pesticides			23
A. Air or Water Environments		1	
1. Aquatic Biodegradation	1		
B. Soil Environment		1	
1. Removal of Agent	1		
C. Adverse Effects - Plant		8	
1. Herbicide Testing	3		
2. Insecticides	2		
3. Bacteriological Anti-Crop Agent	2		
4. Aquatic Plant Control	1		
D. Adverse Effects - Man and Animals		6	
1. Chemical Warfare	3		
2. Use of Non-toxic Material	1		
3. Soil-litter Invertebrates	1		
4. Fungicides	1		

Appendix C (Continued)

Research Area	Number of Research Tasks		
E. Adverse Effects - General		3	
1. Herbicides	2		
2. Aerial Defoliants - Insecticides	1		
F. Analysis, Monitoring and Instrumentation		4	
1. Field Testing	2		
2. Field Dispersal Kit	1		
3. Long Term Effectiveness	1		
Radiation			95
A. Sources		7	
1. Neutron and Gamma Sources	3		
2. Fallout	2		
3. Microwave - Radar	1		
4. Ionizing Radiation, Ultra Violet	1		
B. Effects		67	
1. Radiation	26		
2. Fallout	7		
3. Radiation on Plants	3		
4. Microwave - Radar	8		
5. Materials Testing	4		
6. Laser	7		
7. Eye Damage	9		
8. Extremely Low Frequency Radiation	2		
9. Cell Response	1		
C. Measurements		21	
1. Radiation	8		
2. Fallout	4		
3. Laser	3		
4. IR, Radiofrequency, Microwave	3		
5. Nuclear Studies	2		
6. Eye Safety	1		

Appendix C (Concluded)

Research Area			Number of Research Tasks		
Noise					53
A..	Air Transportation			28	
	1.	Aircraft	15		
	2.	Health Hazards	4		
	3.	Noise Suppression	4		
	4.	Airport Runways	2		
	5.	Transmission	1		
	6.	Supersonic A/C	1		
	7.	Wind Tunnels	1		
B.	Surface Transportation			1	
	1.	Highways	1		
C.	Urban and Industrial Sources			0	
D.	Aquatic Environment			3	
	1.	Noise Reduction	2		
	2.	Ambient Noise	1		
E.	Effects, Measurements, Equipment			21	
	1.	Human Ear Physiology and Psychology	12		
	2.	Noise Suppression	4		
	3.	Speech Communications	4		
	4.	Social Impacts	1		

Source: Environmental Protection Research Catalog, Stock No. 5501-0364, Supt. of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1972).